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THESIS

THE EVOLUTION
OF
THE U.S. HELICOPTER INDUSTRY

by

Murray D. Sheil

December 1984

Thesis Co-advisors:

D. C. Boger
J. E. Ferris

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The Evolution
of
the U.S. Helicopter Industry

by

Murray D. Sheil
Commander, Royal Australian Navy

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

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December 1984

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ABSTRACT

The first production helicopter in the United States was produced by Sikorsky Aircraft (now a division of United Technologies) in 1941 as a direct result of a U.S. Army Air Corps requirement. Helicopter technology advanced rapidly, driven mainly by U.S. Department of Defense research and development funding. The business base expanded as commercial operators became more aware of helicopter capabilities made available through advancing technology. Many competitors were attracted to the industry, including a number from overseas. This thesis examines the growth of the U.S. helicopter industry and explores the issues that have led to the success or failure of the industry's competitors. A particular issue addressed is the role the Department of Defense has played in shaping the industry. The work concludes with an analysis of the current state of the industry and the prospects for its future.

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I. INTRODUCTION

A. BACKGROUND

When the Chinese developed a flying top in the fourth century BC, they began the saga of vertical flight. Progress was painfully slow, and it was not until 1907 when helicopters built by Breguet and Cornu in France achieved the distinction of genuine vertical flight. The early pioneers became convinced that the sole factor limiting helicopter development was the lack of a suitably powerful propulsion unit. When the Wright brothers demonstrated the viability of heavier-than-air powered flight in 1903, the prospects of rapid helicopter development appeared promising. In reality, however, the development of more powerful engines merely brought the early designers face to face with a myriad of unanticipated design problems that were to cause the helicopter industry to lag the fixed wing aviation industry by a span of thirty to forty years.

Early helicopter development was conducted in Russia, France, Germany, England, Spain, Italy, and the United States in the period 1900 to 1940. The first United States military contract for the construction of a helicopter was signed by Georges de Bothezat in 1921. This helicopter flew, but not well, and it did not lead to production. Some relatively successful results were obtained in France and

Germany in the late 1930s, mostly with helicopters designed by Professor Heinrich Focke, but European progress was delayed by the advent of World War II.

The helicopter industry was finally born in 1938 when the Dorsey Bill was presented in the United States House of Representatives, and shortly afterwards became Public Law 787, authorizing the expenditure of \$2 million for the research and development of rotary wing aircraft. In 1939, Public Law 61, passed by the Seventy-Sixth Congress, appropriated \$300,000 for helicopter development. [1:18]

Thus began a long history of United States military involvement in the shaping of the development and structure of the world helicopter industry. The first successful U.S. military helicopter contract was performed in 1940 by Igor Sikorsky who is generally regarded as the father of the helicopter industry. Sikorsky's XR-4 was delivered to the U.S. Army at Wright Field, Ohio in May, 1942. This success prompted considerable military interest, coming as it did during World War II, and a series of military contracts explored many helicopter applications.

Available technology constrained the industry until the advent of the Korean conflict stimulated rapid technological advancements, the most significant being the turbine engine, with its substantially superior power-to-weight ratio. Many United States manufacturers were attracted to the industry but few survived.

European helicopter development, delayed by the chaos following World War II, was stimulated by the transfer of United States helicopter technology through licensing agreements granted by the more successful U.S. companies. Four major European manufacturers emerged; Westland (England), Aerospatiale (France), Agusta (Italy), and Messerschmitt-Boelkow-Blohm (MBB-Germany).

U.S. industry development continued with considerable military research and development sponsorship and four major U.S. manufacturers emerged; Sikorsky Aircraft, Bell Helicopters, Hughes Helicopters, and Boeing-Vertol. Many other companies, including such notable names as Lockheed, McDonnell, Kellet, Kaman, and many other smaller firms were unable to achieve military quantity production and did not survive as helicopter manufacturers.

Civil applications have been slow to develop and the civil market did not achieve significant proportions until the 1970s, when the off-shore oil rig support and corporate/executive markets blossomed.

The U.S. helicopter industry is small compared to the total United States aerospace industry. U.S. helicopter deliveries in 1982 were approximately \$1.4 billion compared to U.S. civil transport sales of \$6.2 billion and general aviation aircraft sales of \$2.0 billion [Ref. 2]. Growth of the industry has been steady, albeit susceptible to the volatile requirements of the U.S. Department of Defense (DoD).

A significant trend has been the penetration of the U.S. commercial market by the European makers, notably Aerospatiale of France.

The U.S. helicopter industry is on the verge of its greatest challenge yet, the transition into the fourth generation of helicopter technology as a result of two significant military programs, the Joint Services Vertical Lift program (JVX) for the Navy and Marine Corps, and the Light Helicopter program (LHX) for the Army. Both programs offer substantial production quantities. The rewards for the winners of these technology advancing competitions will be continuing military workload and the application of this technology to civil derivatives leading to greater access to the civil market. The losers may not survive.

B. RESEARCH QUESTIONS

1. Primary Research Question

What are the critical factors that have affected the development and evolution of the U.S. helicopter industry?

2. Subsidiary Research Questions

a. First Subsidiary Research Question

What customer/market segments have declined or emerged and how have they affected the evolution of the U.S. helicopter industry?

b. Second Subsidiary Research Question

How have military requirements affected the U.S. helicopter industry?

c. Third Subsidiary Research Question

Who have the U.S. helicopter industry competitors been and what factors have led to their success or failure?

d. Fourth Subsidiary Research Question

How has the global helicopter industry affected or been affected by the U.S. helicopter industry?

e. How has technology growth affected the U.S. helicopter industry?

C. RESEARCH METHODOLOGY

The research effort for this thesis relied primarily on two data sources. The first was a comprehensive review of available published literature, in the form of relevant books, industry journals, periodicals, newspapers, and industry and trade association documents. Secondly, interviews were conducted with the strategic planning departments of the previously listed four major U.S. helicopter manufacturers. A valuable source of data and opinion was the American Helicopter Society (AHS), Washington D.C. This society was incorporated in June, 1943, with the constitutional purpose of "collecting, compiling, and disseminating information concerning the helicopter" [3:57]. In this way it set out to represent the industry as a whole, and as such was a valuable source of balanced industry comment and flavour.

D. SCOPE OF STUDY

The object of this research effort is the development of the U.S. helicopter industry. Considerable attention has been given to past U.S. industry history, in particular the impact of U.S. DoD requirements on the industry. This focus was dictated by a prior perception that the helicopter industry was shaped by the provision of military research and development funding. Technology growth was also considered in some detail but generally in the context of its impact on the strategic and business issues leading to competitive advantages or disadvantages.

E. LIMITATIONS OF STUDY

Given that the thesis focuses on commercial strategic and competitive issues, the company interviews were understandably guarded and non-attributable. They did serve to provide both a flavour to the written word unearthed during the literature review and a source of individual company product line development and statistical production data.

The thesis does not address the financial performance of the companies, the reasons for this being three-fold. Firstly, the major companies are all now subsidiaries or divisions of large corporations and accordingly their individual line-of-business financial data are buried inside consolidated financial statements. Secondly, the financial performance of any of the major firms is unlikely to be a significant

factor in the short term, there being an adequate source of corporate funds to overcome a transient and maybe unpredicted cash flow problem. Obviously, sustained poor financial performance would be cause for concern and, perhaps, ultimate company failure, but this would be the result of a deeper, underlying cause (e.g., failure to win production contracts). Thirdly, such research effort would have detracted from the primary focus, i.e., the impact of military requirements.

The thesis also does not address supply side issues. The resource base, in terms of raw materials, sub-contract supplies, labour, and capital, is an obvious contributor to the overall competitive situation but was considered to be beyond the scope of this effort, which focuses on the relationship between the prime manufacturers and their markets/customers.

F. ORGANIZATION OF STUDY

Chapter II provides an historical background of the early development of helicopter theory, providing some insight into those aerodynamic and technological factors that delayed the birth of the industry. The coverage is extended to the late 1930s/early 1940s when Igor Sikorsky produced the world's first viable production helicopter for the U.S. Army.

Chapter III describes in relatively general terms, the development of the U.S. helicopter industry and its market,

indicating the key developmental milestones and issues. It concludes with a quantitative analysis of the growth of the U.S. helicopter industry in the context of the free world industry and some detailed comment on the development of Aerospatiale of France.

Brief profiles of the major competitors are provided in Chapter IV, together with comments on companies that did not survive and a brief review of Soviet helicopter development.

The U.S. helicopter industry developed in generations (piston-engined and turbine-engined). The fourth generation will be introduced by the JVX and LHX programs. These issues are addressed in Chapter V.

Chapter VI explores the role of technology and the approach adopted by countries and makers to technology development. A consistent complaint of U.S. makers is their claim that European governments are more supportive of civil market oriented research and development than is the U.S. Government.

A consistent perception, both throughout the readings and the interviews, is the widely held view that the U.S. helicopter industry is driven by the U.S. DoD in its development of military requirements, this technology being transferred to civil derivatives of military airframes. This aspect is examined in Chapter VII.

Chapter VIII examines, in some less detail, financing, pricing, co-production, government incentives, and manufacturer/government relations.

The study concludes with Chapter IX, which is devoted to the future prospects of the industry, in terms of markets, product lines, technology, and competition.

The study conclusions are presented in Chapter X.

II. HISTORICAL BACKGROUND

A. INTRODUCTION

The development of the helicopter has taken place over many years. However, as depicted in Alvin Tofler's "Future Shock", [Ref. 4], the growth of knowledge has been far from linear. The transition from fantasy to theory, from theory to first stumbling flights, thence to practical reality and finally to today's technologically complex helicopter systems has been fraught with difficulties and frustrations. This chapter will briefly address the early development of helicopter theory and the transition to practicality, in order that the growth restraining factors of the industry can be better understood.

B. EARLY DEVELOPMENT OF HELICOPTER THEORY

When the Chinese developed a flying top that could fly under its own power in the fourth century B.C., they began the saga of vertical flight. The concept remained as a toy until Leonardo da Vinci proposed the first full scale helicopter in 1483 with his now famous design for a lifting screw (the "helix"). This one event aside, the idea of the helicopter did not gain momentum until 1768 when a French mathematician, J.P. Paucton proposed that the classic Archimedean water lifting screw could be used for human flight. Sixteen years later, in 1784, two Frenchmen, Launoy

and Bienvenu, developed the first toy helicopter with a rotary wing, able to take off under its own power. It was not realized at the time, but the device had overcome two fundamental barriers to helicopter development. It had a self contained power source, and the use of counterrotating propellers overcame the problem of torque, the force that tends to drive the body of a single rotor device in the opposite direction to that of the turning shaft [1:18]. Lacking a suitable power source, they were forced to put aside their ideas for full scale development.

An Englishman, Sir George Cayley, inspired by the toy helicopter, is credited by many with producing the first modern helicopter design in the early 1800s. This design used counterrotating rotors on either side of a canvas covered fuselage, with an additional pair of pusher propellers at the rear for forward flight. Cayley, also, did not get his design off the drawing board, realizing that heavier-than-air vertical flight required a more powerful propulsion system than was available at the time.

In 1878 an Italian, Forlanini, built a steam powered model helicopter that flew for twenty seconds at forty feet. This was followed in the 1880s by Thomas Alva Edison who attempted to achieve vertical flight by mounting experimental rotors on a vertical shaft powered by an electric motor. His experiment failed but he continued to believe in the helicopter, concluding, like many before and after him, that

a successful helicopter would not be built until an engine that weighed no more than forty-two to sixty-three ounces for each horsepower produced could be developed [1:5]. He did, however, predict that

Whatever progress the aeroplane might make, the helicopter will come to be taken up by the advanced students of aeronautics. [5:25]

Early experimenters, believing that propulsion power was the only obstacle, were rewarded in the early 1900s with the development of much more powerful gasoline engines. These engines that enabled the Wright brothers to make the first powered flight in 1903 did indeed permit the early pioneers of vertical flight to move from theory to reality. What they also did, however, was to bring the designers face to face with the other problems of stability and control, hitherto not really considered.

C. TRANSITION FROM THEORY TO PRACTICE

In 1907, Breguet (of France) built a helicopter that rose vertically to a height of two feet and remained there for two minutes. This tethered flight was followed in 1908 and 1909 by two more models but all were plagued with a power-to-weight ratio problem, as well as difficulties with stability and control. Paul Cornu of France, is credited with the first helicopter "free-flight" when his aircraft rose to one to five feet for twenty seconds in 1907, but his design experienced the same power, stability, and control problems.

In the early 1900s, Igor Ivanovich Sikorsky, a young Russian from Kiev had been dreaming about helicopter flight for years. He firmly committed himself to the creation of flying machines and chose the helicopter as the "likeliest instrument for his ambition" [5:32]. His first two designs in 1909 and 1910 were not successful but he remained convinced of the reality of his dream. As did others before him, he realized that powerplant availability was a problem and transferred his attention to fixed wing aircraft, achieving success with the 9000 lb. Bolshoi-Balitsky, the world's first four-engined aircraft. He was not to return to helicopters until the 1930s, but his return at that time would launch the helicopter industry.

In the meantime, many other efforts contributed to the development of helicopter theory and practice. During World War I, Lieutenant Stephan von Petroczy of the Austrian Army Balloon Corps and Professor Theodor von Karmon built an electrically powered machine. Whilst not totally successful, this experiment provided some insight into the importance of centre-of-gravity as related to stability and control.

Then, as a significant forerunner of the way the industry was to later achieve its birth, the U.S. Army Air Corps undertook its first important vertical flight program. Army interest had begun in 1918 just after the Armistice, when the Army foresaw great possibilities for "a machine capable of up-and-down flight and hence operation from restricted

areas" [6:88]. In 1921, the Army commenced a helicopter project, funding George de Bothezat, a refugee from revolution-torn Russia. His machine flew on December 18, 1922, seven months behind schedule, rising to a height of thirty feet with its 220 horsepower engine and its 3600 lb. airframe. The Army, however, was unconvinced of the practicality of the design and cancelled the project after spending some \$200,000. An Army report on the project drew attention to the inherent dissymmetry of his multiple rotor-machine (should mechanical failure occur) and its general mechanical complexity, stating that:

Until these defects can be eliminated, the future development of the helicopter proper appears to rest rather in the single-screw type and the reasons for this are at least strong enough to warrant the building and testing of such a type before multiple-screw types are adopted. [6:88]

The paper, in recognizing that the Army saw a need and a use for the helicopter, noted that the de Bothezat helicopter contributed a definite step forward in helicopter progress that could not have been achieved without the expenditure for building a machine and flying it.

Several helicopters were built in the United States in the 1920s by Emile Berliner (the inventor of the Victor phonograph) and his son Henry. Like many predecessors, they chose to solve the torque problem by using counterrotating rotors. They experimented over a five-year period but gave up in the face of problems they could not resolve.

On May 4, 1924, Etienne Oehmichen (France) succeeded in flying the first one kilometer closed circuit course and collected 90,000 francs prize money for his efforts. His helicopter had four main rotors, each with two blades, and five small horizontal variable/reversible pitch propellers.

On April 18, 1924, Marquis Pateras Pescara (Spain) established a world straight line distance record of 736 meters in his four bladed biplane rotor system machine. The significant contribution of this machine was the ability of the rotors to turn freely in the event of an engine failure. As the aircraft neared the ground, the pitch of the blades was increased to use the remainder of the stored energy in the rotor system and land softly. This concept is called autorotation, and is still an important feature of the modern helicopter.

Dutch engineer A. G. von Baumhauer was one of the first pioneers to use a counterrotating tail rotor to compensate the single main rotor torque. He also developed the swash plate system, a device (still in use today) that varied the blade angle of the rotor periodically to stabilize and control the machine [1:12].

In 1930, Italy's Corridion D'Ascanio set many records with his unique helicopter design that featured another significant technological development, the system for feathering the main rotor blades. This involved the development of a hinge system that allowed the blades to be rotated

around their longitudinal axis, thereby changing the pitch angle of the blades and changing the lift. It also featured counterrotating blades but its overall complexity prevented complete success.

Nicolas Florine, of Belgium, developed a radically new design in the early 1930s. This design featured rotors located at the fore and aft ends of the fuselage and it first flew in April, 1933. The design was the forerunner of the tandem rotor helicopter configuration still being used today to meet many heavy lift requirements [1:14].

In 1935, Breguet returned to helicopters and, with Rene Dorand, achieved with the Breguet-Dorand Giroplane what many consider to be the first real helicopter. The Giroplane had two four-bladed counterrotating rotors, a system permitting each blade to adjust itself in flight to the dynamic forces to which it was subjected.

Simultaneously, Professor Henrich Focke was achieving considerable success in Germany, establishing a series of world records for speed, altitude, endurance and controlled flight. His helicopter had two rotors, each having three articulated blades, mounted at the end of each of two wings. Focke considered this the best way to overcome torque and to eliminate vibration inherent in the design that mounted rotors one on top of the other. The success of his machine elevated the helicopter to a new plane of public awareness [1:15].

The dream of vertical flight might not have been realized but for the work of a young Spanish aristocrat named Juan de la Cierva, who "made a breakthrough that brought the elusive helicopter to the threshold of reality" [5:51]. After many years of experimentation that commenced in 1910, he developed the la Cierva autogiro that resolved the problem of relieving the high dynamic stresses developed at the rotor hub of rigidly mounted blades. The autogiro, having a free-wheeling, unpowered rotor, did not encounter the torque problem that plagued early helicopter pioneers but it retain two other problems, i.e., the gyroscopic resistance to being tilted out of its plane of rotation and the inequality of lift generated by the advancing blades and the retreating blades. To counter these stresses, la Cierva developed the flapping hinge and the lag-lead hinge and by 1927 had successfully incorporated his articulated rotor design into practical flying machines, thus passing out of the experimental stage. It was perhaps la Cierva's work that led Breguet to incorporate the articulated rotor into his successful 1935 giroplane.

Owing to British Air Ministry interest and funding, la Cierva had located himself in England. His manufacturing company was unable to meet demand for his inventive machine, although it produced ninety machines. In the late 1920s he granted production licenses to foreign manufacturers, including Japan (where 240 were built), France, Germany and Russia.

Airplane builder Harold Pitcairn bought the United States franchise and built 58 machines before sublicensing the Kellet brothers, who produced a further 22 machines. The machine was put to many uses that will be explored in Chapter III. [5:61]

The craft was given official recognition in 1931 when President Herbert C. Hoover presented the Collier Trophy to Harold Pitcairn for the "greatest achievement in aviation" for bringing the la Cierva autogiro to the United States. The design was further improved in the United States and the autogiro achieved great civil success, to the point where the United States Department of Commerce authorized development of a "roadable" autogiro that could be used on the road as well as in the air. This machine flew in 1936. A combination of economic conditions arising from the depression and high operating costs relative to conventional craft spelt the end for the autogiro.

But if this strange machine with whirling wings was showing signs of being an economic and technological misfit, its developers had achieved at least one signal feat. For by solving the autogiro's problems one by one, la Cierva and his colleagues had opened the way at last for the practical helicopter. [1:36]

So by the end of the 1930s problems such as the lack of power, stability, control and torque had largely been overcome. All the significant technological breakthroughs had been made and the conceptual designs tried and tested in a myriad of different models throughout the United States and

Europe. The helicopter industry was waiting only for the integration of these concepts into a single machine. The man who provided this skill was Igor Sikorsky.

D. THE BIRTH OF THE HELICOPTER INDUSTRY

Igor Sikorsky, after temporarily giving up his helicopter ambitions in 1910, achieved considerable success in Russia as an aircraft designer during World War I. Following the Communist revolution of 1917 he lived in Paris for a while before proceeding to the United States. After some hard times, he founded the Sikorsky Aeroengineering Corporation in 1923, using borrowed money. The corporation began building the S-29A, an all metal twin engine transport. Over the next few years Sikorsky produced nine planes of various types but the corporation did not achieve great success until 1928, when the S-38 amphibian won wide acclaim. By 1929, Sikorsky was producing a much larger flying boat for Pan American Airways and Sikorsky renamed his company the Sikorsky Aviation Corporation and moved his plant to Stratford, Connecticut.

At this time, the company ran into financial difficulties and became first a subsidiary and then a division of the United Aircraft Corporation. This action provided him the opportunity to return to his dream of the helicopter. In late 1930 he wrote a memo to the management of United Aircraft, stating that,

...a helicopter that could land on the top of buildings, on ships, and in tiny parks could be built. He urged

the company to develop in a reasonable and economic way its own type of helicopter. [5:78]

The onset of the depression destroyed any chance his proposal may have had and his company continued to achieve success in the fixed wing field. He continued his private efforts with helicopters, however. The continuation of the depression and increasing competition in the fixed wing field led to a decision, in 1938, by United Aircraft, to close down the Sikorsky division. However, the company did suggest that it would be open to the undertaking of a personal research project by Igor Sikorsky. Sikorsky immediately suggested the helicopter and requested that his team of expert engineers be retained.

Sikorsky had given much thought to helicopter configuration and finally decided to pursue an idea that he had patented several years earlier, that of a single main rotor and a small vertical tail rotor. The technology of the autogiro was also crucial to his work, with Sikorsky pointing out several years later that the

...The autogiro was the important missing link between the fixed wing concept and the helicopter concept. Without a doubt, the technology of the rotor head and blade, developed for the autogiro, was of significant use in the development of the helicopter. [1:48]

After much company funded work, the result of Sikorsky's efforts was rolled out on September 14, 1939. The first flight, although only a few inches and for a few minutes, occurred on that day. Sikorsky then began a series of

"hit-or-miss" alterations to dampen vibrations and balance the flight controls. On May 13, 1940, Sikorsky achieved the first free flight of his helicopter and Sikorsky's secret became public as the now famous VS-300 and the prototype of the world's first viable production helicopter.

The U.S. Army Air Corps had cancelled the de Bothezat helicopter project in the mid 1920s and Army enthusiasm for helicopter development had waned for several years. W. Laurence LePage (an engineer for the Pitcairn Autogiro Company and later for the Kellet Autogiro Company) and Havilland H. Platt (a mechanical engineer from New York), formed a company in 1938 for the express purpose of building a vertical flight capable aircraft. This alliance produced the Platt-LePage helicopter, the PL-3, and led to an Army contract on July 19, 1940, for the Army's second helicopter, the Platt-LePage XR-1. The Army also let contracts with the Kellet Autogiro Corporation for the XR-2 and the XR-3 autogiros.

But the Army was not satisfied with just one type and expressed interest in the Sikorsky VS-300. In July 1940, Captain "Frank" Gregory, of the Army, arrived at Sikorsky to test fly the VS-300. This event was significant for the helicopter industry because Gregory was the project officer for the embryo United States Army Helicopter Program. As a result of this flight, Gregory recommended that the Army sponsor the development of the VS-300, despite a commitment

to the Platt-LePage XR-1. Sikorsky was provided with a contract and \$50,000 to build an experimental helicopter (the XR-4) for the Army Air Corps. The XR-4 was to be twice the size and twice as powerful as the VS-300. The Platt-LePage machine, because of its size, had to undergo many developmental changes while Sikorsky was able to make definite progress with his XR-4 design. The XR-4 was finally delivered to the Army Air Corps at Wright Field, Dayton, Ohio, after a spectacular five-day, sixteen-hop delivery flight that broke nearly all existing helicopter flying records.

In December, 1942, after the completion of extensive testing, the Army contracted for production to begin and also placed an order for a new larger model, the XR-5. Shortly after, in April, 1943, the Army requested yet another version, the XR-6. Meanwhile, the Platt-LePage experimental model was encountering difficulties and did not win a production contract. In Germany, Allied bombing raids were disrupting the planned production of Henrich Focke's FA-123 helicopter. Through this combination of events, and a clearly technologically superior product, Sikorsky was able to take an early lead in helicopter design and manufacturing. Sikorsky had established an early but significant competitive advantage and the helicopter industry had been born [5:84].

III. THE U.S. HELICOPTER INDUSTRY - DEVELOPMENT AND MARKETS

A. INTRODUCTION

The analysis of the development of the U.S. helicopter industry and its markets presents a dilemma. The growth of the industry is conceptually simple, with key growth milestones being dictated by major military events, i.e., World War II, the Korean conflict, and the Vietnam conflict, and with the commercial/civil helicopter users accepting minimally adapted military derivatives for a variety of applications (at least for the first thirty years of the industry until the 1950s).

Within that simplistic context, however, the detail of industry growth is incredibly complex, with the major manufacturers presenting a myriad of proposals for the numerous military competitions. It was tempting, when conducting this analysis, to describe every procurement in detail, but it soon became apparent that this approach would disguise the key events and issues leading to industry growth. Accordingly, the discussion that follows addresses only those events that have contributed significantly to that industry growth, and the astute or well-informed reader may consider that several events have been omitted.

B. MILITARY DEVELOPMENT

1. The Beginning - 1938 to 1950

The helicopter industry was initiated when the Dorsey Bill was presented in the House of Representatives in 1938. It soon became Public Law 787 and authorized the expenditure of \$2 million for the research and development of helicopters. The following year Public Law 61 was passed by the Seventy-sixth Congress, appropriating \$300,000 for the purpose of developing the helicopter [1:18]. This rapidly led to the award of military contracts to the Platt-LePage Aircraft Company and the Vought-Sikorsky Division of United Aircraft. Platt-LePage was unsuccessful but Igor Sikorsky won production contracts from the Army for his R4, R5 and R6 series helicopters, having previously developed the VS-300 helicopter with company funds. These events demonstrated three characteristics of the industry that have remained dominant throughout its life: the driving of the industry by military conflicts (in this case, World War II), the role of the military in specifying and dictating military requirements, and the military tendency to order back-up or parallel production to reduce program risk.

In Europe, pre-war helicopter technological progress had been halted by World War II. The early post-war attempts by Breguet (France) and Focke (Germany) ended in failures. In the United States, however, the U.S. designers quickly found themselves in the position of being world design and

production leaders. By V-J day (September, 1945) Sikorsky had produced 617 helicopters, the only manufacturer worldwide to have entered production [1:29]. During this period many helicopter applications were explored, ranging from the dropping of munitions, emergency medical and rescue use, mail deliveries, aerial photography, shipborne operations on the Army transport BUNKER HILL, amphibious operations (with floats), mosquito spraying, rescue hoist operations, construction work lifting, wire laying, and off-shore operations (in support of floating repair depots off Okinawa). Whilst these roles were well demonstrated most were not yet practical or economical due to payload restrictions [1:30].

By the time World War II ended, Sikorsky (having produced 617 aircraft for the military) had been joined by Bell (just completing its third prototype, the Model 30), Piasecki (flying the PV-3, the origin of the well-known Boeing-Vertol family of tandem rotor helicopters), Hiller (developing the KH-44, the first co-axial helicopter in the United States), and several other companies (Platt-LePage, Kellet, Bendix, Firestone and GCA, all developing their own unique prototypes) [7:154].

In 1942, Igor Sikorsky had predicted that in the future hundreds of thousands of helicopters would be produced at prices comparable to those of automobiles. This was a similar hope that Harold Pitcairn had held for his autogiro in the 1930s, but the dream had not been supported by

technology. With more than 70 companies working at helicopter development in the mid-1940s, technology had advanced considerably and there was great interest in the establishment of short haul helicopter services. Even the Greyhound Bus Company had filed an application to start an intercity helicopter service [5:99]. However, only a select few of the many design efforts were to succeed.

Sikorsky had already established his production capability by the end of World War II. Piasecki made progress with his PV-3 tandem rotor design. By spreading the load between two rotors, each rotor would be smaller and simpler than an equivalent lift single rotor. Additionally, cargo could be loaded almost anywhere in the long "flying banana" shaped fuselage without upsetting the centre-of-gravity. The concept also proved very attractive to Navy and Marine Vertical Replenishment (Vertrep) pilots because the aircraft could be hovered out-of-wind (the single rotor design of Sikorsky being sensitive to wind direction). These design concepts were sufficiently important to allow Piasecki to win important contracts for his tandem rotor designs of the HRP-1 "Flying Banana" that saw Navy, Marine and Coast Guard use.

The Navy version was evaluated for anti-submarine warfare (ASW) use [8:260]. Over the next two decades, the proven tandem concept would evolve into a variety of capable, multi-purpose helicopters produced in large quantities [5:100].

Arthur Young produced the Bell Model 30 for Bell Aircraft Corporation. The Bell design was similar to the Sikorsky single main rotor/single tail rotor but employed only a two-bladed rotor system. Being very simple, this helicopter could be produced very cheaply and soon evolved into the Bell Model 47. It was the first helicopter to achieve civil certification, in 1946.

Stanley Hiller formed his own company, and after experiments with co-axial designs, he developed his innovative and highly successful "rotomatic" rotor system [1:35] for use on the conventional single main rotor design approach. His Model 360 became successful, achieving civil certification in 1948.

Charles Kaman adopted the intermeshing rotor principle employed previously by Flettner in Germany in the 1930s. He had proposed this approach to United Aircraft, when he had been employed as Chief Aerodynamicist, but was refused, owing to the Sikorsky commitment to a single rotor design. He formed his own company in the late 1940s and was persuasive enough to win contracts from the Navy, Air Force, and Marines [5:102].

By 1949, a new generation of helicopters had been produced and five helicopters had received civil certification: the Sikorsky S-51 and S-52, the Hiller 360, the Kaman 190 and the Bell 47. On November 19, 1949, the Sikorsky H-19 made its first flight and proved it could carry 10

passengers and a crew of two more than 350 miles. This aircraft made possible, for the first time, a serious consideration of vertical envelopment of battlefields by helicopter borne troops [9:45]. The Sikorsky H-19 (commercial designation S-55) had been produced as a contract modification to an Air Force contract for the production of the Sikorsky S-51, which had initially been produced using company funds following the decline of military orders after World War II. This sequence of events was crucial to Sikorsky, leading to a production of nearly 2000 H-19/S-55's and access to further development contracts. It also led, ultimately, to Sikorsky's dominance in the ASW helicopter market.

By the end of the 1940s, almost 1000 helicopters had been produced and used in many military applications. The Marines, using the Piasecki "Flying Bananas", had experimented with the vertical envelopment concept, but the Army was prevented from using this aircraft in the battlefield by a bureaucracy that determined that Army aviation was restricted to aircraft weighing two tons or less.

2. The Korean Conflict - 1950 to 1960

When the Korean conflict broke out, the early helicopters were used for scouting. These were primarily Sikorsky S-51s that were not suited to medical evacuation. Between the wars the Army Medical Corps had developed the Mobile Army Surgical Hospital (MASH) concept. In so doing, they sponsored the Bell 47 observation and medical evacuation

helicopter. This private venture helicopter had been produced by Bell in large numbers in anticipation of a civil market that did not eventuate. Thus, when required in large numbers for the Army, the Bell 47 was able to defeat its only competitor, the Sikorsky S-52-1 (a development of the early Sikorsky R6) which was not production ready.

Hiller was also able to capitalize on the Korean conflict with a military version of his commercial Hiller 360, the Army H-23 Raven which was used extensively for observation, casualty evacuation, and general utility purposes.

By the end of the Korean Conflict in mid 1953, Bell had produced more than 1200 helicopters, Piasecki about 380, Sikorsky about 1350 and Hiller about 530. The Korean War had established the use of the battlefield helicopter, primarily in the medical and transportation roles and had given Sikorsky, Bell, Hiller, and Piasecki significant military production contracts. Further, the product line orientation of the companies was also established with Sikorsky and Piasecki producing larger, more complex helicopters and Bell and Hiller producing light simple helicopters.

The French experience in Indochina during the same period saw the use of a number of Sikorsky H-51s and the larger H-19s, and two Hiller 360s. Their contribution to the war was not significant in material terms, being used almost exclusively for medical evacuation missions but the experience had a profound effect on the French military, who

used helicopters extensively in the Algerian theatre. By the time of the Algerian cease fire in 1962,

The French had concentrated no less than six hundred helicopters in that country: 380 troop carrying craft of the H-34 and Vertol H-21 type; 21 medium craft of the S-34 and H-19 type and about 200 light helicopters mainly of the Alouette type. The French also had experience with arming these helicopters with a variety of guns and rockets. [8:3]

The French began a strong domestic helicopter industry in this period but British production relied mainly on licensed production of Sikorsky-developed machines. Whilst the U.S. Marines had conducted the first "vertical assault" exercises with helicopters as early as 1948, the British launched the first combat helicopter assault in November 1956 in the Suez. British-produced Sikorsky licensed helicopters were used in "police" operations in Africa and Asia, Kuwait, Tanganyika, Malaysia, Sarawak, Sabah, and Borneo [8:8].

3. The Vietnam Conflict - 1960 to 1970

The final military transition to helicopters came with the Vietnam war. This conflict provided the greatest single impetus to the world helicopter industry. The period after Korea and before Vietnam had seen an increasing military interest in the concept of "air mobility" and the helicopter war. Sikorsky and Piasecki continued to compete in the heavy helicopter arena. Piasecki had won a 1950 competition for an Air Force air rescue helicopter with the H-21 Workhorse. The Sikorsky S-58 (military designation

H-34) was produced concurrently under an Air Force contract modification to the previous Sikorsky H-19 contract. The demands of the Vietnam War ensured that both companies would receive substantial production orders. [1:37]

The arrival of 32 U.S. Army H-21 helicopters in Vietnam in December, 1961,

...was the first major symbol of United States combat power in Vietnam; and it was the beginning of a new era of air mobility in the United States Army. [8:8]

These helicopters were joined in April, 1962, by a Marine helicopter squadron of Sikorsky H-34s. By the late 1960s there were several thousand helicopters in South Vietnam. In late 1961, Secretary of Defense McNamara had tasked the Army to study its aviation requirements. The resulting Howze Board report led to the establishment of the Army's 1st Air Cavalry Division (Air Mobile) which deployed to Vietnam in 1965, with some 430 helicopters [8:9]

The early helicopters in Vietnam were not armoured and lacked power. However, the Army, aware of this shortcoming in its emerging battlefield helicopter concept, had sponsored engine development programs aimed at producing lightweight turbine engines especially for helicopters. These programs ultimately produced the Allison T-63, the Avco-Lycoming T-53, and the General Electric T-58 engines. The first turbine helicopter was the Kaman 225, which appeared in 1951, but America's first production turbine-powered helicopter did not appear until 1958 (the improved

Kaman 225 pilot rescue helicopter procured by the Air Force as the H-43 Huskie which saw Vietnam service and was Kaman's first long production run).

The mid 1960s saw a new generation of helicopters in Vietnam, as the manufacturers and the military took advantage of the new turbine engines. Boeing-Vertol, successor to the company founded by Piasecki in 1945, replaced the H-21 with two new turbine-powered transports, the CH-46 Sea Knight (designed for Marine and Navy shipborne use and capable of lifting 25 troops), and the larger CH-47 Chinook (designed for the Army and with a 45-troop capacity). Both aircraft relied on the prior Piasecki tandem rotor experience. Sikorsky produced a huge heavy lift aircraft, the twin turbo-shaft powered CH-54 Sky Crane. This aircraft had its roots in an earlier Navy contract that had produced the Sikorsky S-56 (CH-37) which in turn had led to a private venture heavy lift helicopter, the S-60. Sikorsky achieved further success in this period with two large twin-turbine helicopters, the H-3 and the H-53. The H-3 was designed to replace the Sikorsky H-34, whilst the H-53 was a heavy assault version of the Sky Crane [5:140].

The smallest helicopters in the Vietnam conflict were the light observation helicopters (LOHs). This task had previously been conducted by the Bell 47 and the Hiller 360. The Army conducted a competition for the LOH in the mid 1960s which was won by the Hughes OH-6A Cayuse with a

very aggressive pricing strategy. This event marked the entry of Hughes into quantity helicopter production. The two unsuccessful entrants were Bell and Hiller. Bell was able to commercialize its unsuccessful OH-4A as the very successful Bell Jet Ranger series. This helicopter subsequently won a follow-on contract for the LOH as the Bell OH-58 against the Hughes OH-6A.

The most visibly successful helicopter of the Vietnam war first flew at Bell in 1956. It was the simple turbine-powered utility helicopter, the UH-1 Huey. As with the previous Bell 47, Bell demonstrated the ability to continually improve the aircraft and it remained in full scale production for more than twenty years. The Huey superseded the Bell 47 MASH helicopter but it was rapidly assigned to more combative duties. The Huey was initially "jury rigged" with rockets and cannons in the field but factory equipped gunships arrived in 1963 [5:147]. These were too slow to be effective and the Advanced Aerial Fire Support System (AAFSS) project was initiated. This development contract was won by a newcomer, Lockheed. The Army contracted for an interim gunship, won by Bell with their privately funded Cobra, which reached the war in 1967 [5:150].

The American helicopter industry expanded dramatically to produce the surge of helicopter requirements for Vietnam. In their peak year during the war Boeing's Vertol division built 398 CH-46s and CH47s, Hughes delivered 1129

OH-6As and TH-55s, while Bell built 2485 helicopters in one year (UH-1s, AH-1s, and TH-13s). In addition, these firms were producing helicopters for civil use and foreign military services. Sikorsky produced its maximum output in 1957 (467 H-19s, CH-37s and CH-34s) but during the Vietnam war produced fewer but larger machines, including the CH-53 and the CH-54. [8:9]

Thus, the U.S. had a very firm grip on the helicopter market at the end of the Vietnam conflict, but, in addition to the material losses of the conflict (some 4,112 helicopters), a more subtle commercial loss occurred. Up until this time, the major U.S. makers, particularly Bell, Boeing-Vertol, and Sikorsky, had granted overseas licenses to European makers. This factor, allied with the U.S. industry commitment to support the Vietnam conflict with massive military helicopter production, caused a neglect of the export civil market, allowing the European makers to gradually penetrate both the European and domestic U.S. markets [10:148].

At the Vietnam cease-fire in January, 1973, the major U.S. military helicopter makers were: Sikorsky (who had established a dominant position in the ASW market with the S-61 Sea King series, as well as a strong position in the heavy lift and Marine assault markets with the CH-54A and the CH-53), Boeing-Vertol (with the CH-47 Chinook Army and CH-46 Sea Knight Marine Corps transports), Bell (with the Huey and the Cobra), Hughes (with the OH-6A Cayuse and the

Hughes 269/TH-55 Osage trainer), and Kaman (with the H-43B Huskie for Air Force crash rescue).

During this period military requirements responded to advancing technology in the area of ASW, with Sikorsky emerging the victor in competitions first against Piasecki with his tandem rotor designs and then against Bell who had won a 1950 competition with the tandem rotor HSL ASW design. Bell was not able to produce this helicopter and the Sikorsky S-58/H-34 became the Navy's standard ASW helicopter. Sikorsky was then able to upgrade the H-34 by an engineering change proposal to the S-61 Sea King (SH-3) without the requirement to compete. In the late 1960s, budget constraints led to the decommissioning of ASW carriers and resulted in the consolidation of the ASW squadrons with the fighter and attack squadrons in Air Groups on the remaining carriers. This resulted in the S-61 carrying out not only ASW duties but also plane guard/rescue tasks, displacing the rescue helicopter, the Kaman UH-2. The failure of another ASW program, the Drone AntiSubmarine Helicopter (DASH) program, left Navy destroyers without an ASW capability. This provided an opportunity for Kaman to modify the UH-2 to the SH-2 Light Airborne Multi Purpose Systems (LAMPS) Phase I helicopter for the Navy.

At the end of the Vietnam conflict in 1973, Sikorsky, Boeing-Vertol, Bell, and Kaman had survived. Hughes had entered the market aggressively, whilst Hiller had been all

but eliminated by the Hughes entry. Lockheed had attempted to enter with its significant win in the AAFSS competition with the AH-56A Cheyenne, but, faced with many technical, economic, and political problems, was not able to bring the Cheyenne to fruition.

4. The Post Vietnam Era - 1970 to Present

Whilst the survivors had all had long production runs, the post Vietnam era saw a decline in the number of military orders. Sikorsky only had the S-61 Sea King, the CH-54 Sky Crane, and the CH-53 Sea Stallion, all in limited or late production, Boeing-Vertol's production was limited to the CH-47 Chinook, and Hughes had no new military orders in the offing. Bell alone had received a number of orders, for further UH-1 Hueys, AH-1 Cobras, and OH-58 Kiowa reconnaissance helicopters.

The 1970s saw a number of important competitions. The Army held a competition for the Utility Tactical Transport Aircraft System (UTTAS) helicopter to replace the Huey. The design competition was won by Sikorsky and Boeing-Vertol, who were then contracted for prototype development. Sikorsky, in what amounted to a make or break effort, won the fly-off in 1976 with the UH-60 Black Hawk, leading to quantity production with a multi-year contract. This was followed by a Navy requirement for the Phase III LAMPS ASW helicopter. Whilst the requirement was competed, Sikorsky easily won the competition with the navalized Black Hawk. An Air Force

requirement for a search and rescue helicopter is also likely, with Sikorsky being most favoured to win with yet another Black Hawk derivative.

The Sikorsky focus on the heavy end of the market paid dividends when it was able to win a contract in 1973 to develop the CH-53 series to the huge CH-53E Super Stallion by the addition of a third engine. The original design of this series was built with this option in mind. The CH-53E, provided to the Navy and the Marine Corps, is the heaviest heavy lift helicopter produced in the free world.

The other significant post Vietnam competition was the Army requirement for an Advanced Attack Helicopter (AAH). This program, designed to supersede the ill-fated Lockheed AH-56A Cheyenne, was won by the Hughes AH-64 Apache against the Bell YAH-63 in December, 1976. This win has assured the survival of Hughes and was significant enough to lead to the acquisition of Hughes by the McDonnell Douglas Corporation in January, 1984.

Bell has recently won a contract to upgrade the large Army fleet of OH-58 helicopters to the OH-58D standard in the Army Helicopter Improvement Program (AHIP), winning this competition against the Hughes OH-6A Cayuse.

The significant military competitions are discussed in more detail in Chapter VII. The impact of the newly emerging programs (the JVX and the LHX) are addressed in Chapters VII and IX.

C. CIVIL DEVELOPMENT

1. The Autogiros

The practical applications of the helicopter in the civil sector were in fact explored well before Sikorsky demonstrated his famous VS-300 in the late 1930s. Juan de la Cierva had brought the autogiro to the world, and in 1928, became the first pilot to cross the English Channel by autogiro. La Cierva's factory in England produced 90 autogiros but could not meet world demand and in the late 1920s, he granted production licenses around the world. Amongst these, Harold Pitcairn brought the autogiro to the United States. [5:61]

In 1932 Pitcairn was convinced that he could convert public enthusiasm into sales for the autogiro. His slogan, "this year own and enjoy a Pitcairn Autogiro", demonstrated his belief that he had purchased the U.S. rights to the "model T of the air" [5:62]. During the 1930s, his autogiro was put to many practical uses. The New Jersey State Forest Service used an autogiro to fight fires, business corporations flew them in promotional efforts, the Detroit News and the Des Moines Register and Tribune each had one to cover special stories, and they were used for archeological surveys and cropdusting.

After design improvements in the mid 1930s, the autogiro conducted trial takeoffs from a downtown Philadelphia post office roof and the United States Department of Commerce

authorized the development of a "roadable autogiro". The dream was that the autogiro would solve traffic jams, strengthen the national defense, and re-invigorate business [5:66].

Economic conditions prevailed, however, and buyers (among them Eastern Airlines, which used the craft on some of its mail runs), could not afford the increase in operating costs over conventional craft. The craft did not succeed as a product line but it did make a significant contribution to the development of the helicopter and had demonstrated the range of future helicopter applications prior to the initial flight of the first practical helicopter in the late 1930s.

2. The Helicopters

Civil applications of the helicopter were slow to develop. One of the earliest cargo lift demonstrations was conducted in Europe by Heinrich Focke, in December, 1940, when he transported an external load of 1284 kilograms a distance of 2 meters. In June, 1943, he conducted a similar experiment in front of Adolph Hitler, leading to a production order of 1000 (at a rate of 400 per month). Production was only in the early stages (nine completed) when World War II ended, disrupting any further production.

In the United States, early helicopter production was dominated by the military requirements of the U.S. Army Air Corps, prompted by an awareness that the helicopter

could be useful in war. Igor Sikorsky, however, had humanitarian visions of the helicopter:

I could see helicopters carrying people and goods directly to the destination, and not 10 to 15 miles away and then transported there by other means. I also foresaw the helicopters unparalleled ability as a rescue device under the greatest variety of circumstances. [9:15]

In spite of this, history has shown that although virtually every helicopter designer has stressed the rescue role, it is the military potential of the helicopter that has paid for the technological development of the industry. [9:15]

Some years earlier, the Army, in a report on the first U.S. military helicopter development contract (the de Bothezat helicopter, first flown in 1922), was critical of the complexity and poor performance of the helicopter, stating that;

These features are such as to rule out its development except in the case of such military urgency that the life of the pilot and the observer is of little consequence....the future development of the helicopter proper appears to rest rather in the single screw type, and the reasons for this are at least strong enough to warrant the building and testing of such a type before multiple screw types are adopted. [9:19]

Thus the military was attempting to impose its requirements in the very early stages of industry development.

After World War II ended, helicopters developed by Sikorsky (the S-51 and the S-52), Bell (the Model 47), Hiller (the Hiller 360), and Kaman (the K-190) all achieved civil certification by April 15, 1949. The noteworthy

feature of these events was the fact that none of these manufacturers were certain of their civil markets. More importantly, the potential buyers were not aware of the possible range of uses and had to be convinced by the manufacturers.

Tug Gustafson was the first Sikorsky helicopter salesman. When World War II ended, Sikorsky had to decide whether they would build commercial helicopters. Gustafson was sent to Washington, where the uninformed Departments of Agriculture and Forestry advised that if the helicopters could be built, the Forest Service would buy 500 and the Department of Agriculture would buy 200. Sikorsky, believing that the helicopter could be sold by the thousands, decided to build the commercial S-51 with a planned production of 60 for the first year, at a price of \$48,500. First year sales were only 11, falling to three in the second year. Gustafson later said,

We had a helicopter....but we did not know what to use it for. Where we thought that 95 percent of the problems were going to be technical, that marketing them would be simple, we really found out in the first two years that the problem was that there was no market, even though the machine was ready to fly. So the first thing we had to do was to go out and find and develop possible applications. [7:164]

In 1947, Gustafson opened the first shuttles in Boston, which lasted four months before going bankrupt. In the fourth year of production, Sikorsky was selling very few commercial helicopters and they concentrated on the military

market. The Korean War developed the Marine Corps interest in helicopter combat assault and Sikorsky pursued that market, leading them to develop a line of progressively heavier and more capable helicopters, primarily for the military requirements. [7:164]

Bell Helicopters encountered similar difficulties. After developing the Model 47 light helicopter and achieving the first civil certification in the world in 1946, the President of Bell, Larry Bell, stated to his test pilot, Joe Mashman,

Now we have got to try and sell the helicopter, Joe. I want you to go out and demonstrate that machine.
[7:161]

Initial demonstrations were to the U.S. military, but in 1947, the Argentine government decided to buy some helicopters to fight locusts. During a year long program, Mashman operated 12 Model 47s in Argentina and demonstrated them all over Latin America. Mashman later stated,

Right from the start, you found that you demonstrated to people that didn't believe in helicopters....especially in the 1950s and 1960s, the civil and military markets were first learning about helicopters. [7:162]

Tug Gustafson joined Bell in 1948, when Bell was struggling, and trying to develop a commercial business. They formed a company called Bell Aircraft Supply, with four helicopters, four pilots, four mechanics, \$250,000, and a charter to "go find the market" [7:164]. They determined that the agricultural market was promising, and that the

helicopter was the ideal applicator. However, the agricultural program was a disappointment and Bell looked for another market, following a directive from the Board of Directors that they had "90 to 120 days to satisfy the Board that we should keep the industry alive" [7:166]. So Gustafson approached the petroleum industry searching for oil in the swamps of Louisiana and won enough contracts to satisfy the Board. The market he had developed was oil exploration support, gravity surveys, and seismic surveys.

Having developed the market, Bell sold Bell Aircraft Supply for \$100,000 in February, 1949. This new company eventually became Petroleum Helicopter Inc. (PHI), today one of the biggest commercial helicopter operators in the world. [7:166]

Hiller, being one of the few companies formed solely to build helicopters, and without corporate financial support, was struggling to keep alive in 1948, when civil certification for the Hiller 360 light helicopter was obtained. Hiller stated,

When we started production, we didn't know what the market was; we thought it was agriculture, we installed some agricultural equipment; we thought it was rescue, we installed some rescuing equipment. But the customers didn't know how to use them. It was a very dark period in our existence because we had put all this money and effort into a vehicle and we had certified it, we had started production but we had no customers. [7:175]

At this point, a dramatic high altitude rescue in Yosemite by a Hiller 360 (following the failure by Bell and

Sikorsky helicopters to complete the rescue) attracted world-wide attention and led to civil orders for the Hiller 360 rescue helicopters, some deliveries to the French for use in Indochina, orders from the U.S. Army, and survival of the company through this period.

Kaman never really attempted to penetrate the civil market, despite obtaining civil certification for his helicopters in the late 1940s, primarily for cropdusting applications. The Kaman helicopters were designed especially for the Navy and did not really answer commercial needs.

Kaman's test pilot, Bill Murray, stated,

...we never built an aircraft intended for the commercial market at the beginning. [7:185]

Thus, by the early 1950s, the major manufacturers had all attempted, in some way, to sell civil helicopters. The anticipated explosive growth of commercial applications had not eventuated, with potential buyers requiring substantial demonstrations to be convinced. Despite the apparent possibilities, the helicopter was constrained by a lack of power, and consequently, a lack of useful payload, and by a disbelieving and unconvinced marketplace.

Even after the Korean War, all commercial helicopters were direct adaptations of military types, and the helicopter design of the 1960s was commensurate with the fixed wing state of design art of the 1930s. The combination of military hardware and immature design was not a good

formula for commercial success, so the growth of commercial use was very shallow for twenty years. In commercial terms, this slow growth can be attributed to the high capital cost of helicopters, high operating costs (caused by high maintenance requirements), poor payload capability, lack of public awareness of helicopter capabilities, and the lack of all weather flight capability. [10:2]

The Vietnam war, with the vast deployment of helicopters, stimulated a boost in military helicopter technology that was able to be transferred to the commercial sector. The most significant development was the introduction of the turbine engine into the light, 4/5 seat helicopter that opened up a new era in commercial helicoptering. The major beneficiaries of these developments were Bell and Hughes, who had decided to concentrate on this sector of the market, with a philosophy of building helicopters that commercial operators could make money with. Sikorsky and Boeing-Vertol were concentrating on the heavy end of the market. Whilst they did achieve sales in those sectors that required heavier lift and longer range, their helicopters were generally too expensive to buy and operate for the small commercial operator, owing to their very specialized military origins. Additionally, the hoped for airline usage has never developed, primarily because the helicopter cannot compete with a comparable-capacity conventional fixed wing aircraft on the basis of seat/mile costs, the bottom line for an air carrier.

Bell and Hughes were both able to take advantage of military developments to transfer technology to commercial derivatives and to expand the market for many applications of the light turbine-powered helicopter.

Recent development has concentrated on increasing visual appeal, reducing vibration levels, increasing passenger comfort, reducing maintenance requirements, and offering wide ranges of optional kits to make the helicopter easily adaptable to a wide range of applications.

Bell and Hughes have both targeted corporate/executive use, emergency medical service/air ambulance markets, media news gathering roles, agricultural and forestry use, and many public service applications. The helicopter has found a market in the construction and logging industries, and it is in this application that the heavy lift helicopters of Sikorsky and Boeing-Vertol have found some sales.

During the 1970s, the booming civil market was the off-shore oil rig support market. Demand for helicopters in this role is closely correlated with the state of the oil industry and declined in 1980/81. All U.S. makers attacked this market, Bell and Hughes looking at the short-haul market, and Sikorsky and Boeing-Vertol hoping for sales in the long-haul crew change market.

The strength of the commercial market in the 1970s led to the development of the only two U.S. helicopters designed especially for commercial use, the Bell 222 and

the Sikorsky S-76. Boeing-Vertol also developed a commercial version of the Chinook, the Boeing 234. Sales of all three have not been outstanding, due mainly to the falling market caused by the recession and high interest rates of the late 1970s and early 1980s.

The most significant recent occurrence has been the development of the twin turbine light helicopter, which has increased customer confidence through increased safety margins and has increased the payload to empty weight ratio and expanding the range of applications.

Paralleling this airframe and engine development has been the technological advances in helicopter avionic systems, leading to a much improved all weather capability and further expansion of existing markets. [10:4]

The growth of the civil market can be seen by reference to Figure B-4. The growth has been quite dramatic in the last five years, with the corporate/executive market being dominant, largely due to the advent of the improved light turbine helicopters being offered by Bell and Hughes, and the more recent advent of the light twin helicopter. The disturbing factor for the U.S. helicopter industry, however, is the increasing European presence, as indicated by Figure B-9. This issue is addressed in more detail in the concluding section of this chapter.

D. SIZE AND COMPOSITION OF THE U.S. HELICOPTER INDUSTRY

There are a number of difficulties associated with estimating the size and composition of the U.S. helicopter industry. There are numerous sources of data, and results from different sources are not always comparable owing to different methods of measurement. Most data sources publish units produced. In terms of sales volume this can be misleading, e.g., Bell and Hughes produce large numbers of small, relatively cheap helicopters, whilst Sikorsky and Boeing-Vertol produce fewer numbers of more expensive helicopters. Information is not always timely and is frequently revised several years after the event. Aggregate data is relatively easy to obtain, but companies are very sensitive about releasing business segment data, particularly data revealing financial performance.

The analysis that follows is designed to indicate relative trends only and does not purport to provide absolute measures of performance. Numbers have frequently been rounded to make the trend more easily apparent without destroying the credibility of the data.

The data for Tables A-1, 2, A-2, A-3, A-4, A-5, and A-8 were extracted from the internal records of one of the major U.S. helicopter manufacturers and represent an aggregation of data of all of the world helicopter manufacturers.

Free world helicopter production, in units of production annually, is shown in Figure B-1 (data from Table A-1). The

graph clearly indicates the general rising volume for the period 1943 to 1980. The peaks in 1953 and 1968 were caused by the Korean and Vietnam conflicts. The dramatic effect of the Vietnam era is quite apparent. Soviet helicopter production is not included in this data. Whilst good, reliable Soviet data is not available, it has been estimated by one of the U.S. manufacturers that the change in production shares from 1970 to 1980 is as shown in Table 1 below.

TABLE 1

CHANGE IN WORLD PRODUCTION SHARES 1970-1980

	<u>1970</u> <u>(Percent)</u>	<u>1980</u> <u>(Percent)</u>
UNITED STATES	65	40
WESTERN EUROPE	15	17
USSR/EAST EUROPE	16	39
OTHER	<u>4</u>	<u>4</u>
TOTAL PRODUCTION-(UNITS)	3717	3800

These figures indicate a relatively pronounced increase in Soviet market share. Since the Soviet expansion has been mainly in heavy helicopters, the Soviet intrusion is greater in terms of pounds of production, but does not have a great effect on the light and intermediate world helicopter markets.

Annual unit production for the U.S. manufacturers is shown in Figure B-2 (Table A-2) and Figure B-3 (Table A-3). Bell helicopter has dominated production (in units) for all three peaks in 1952/53, 1968, and 1980. Hughes also contributed to the Vietnam peak with production of the OH-6A Cayuse light observation helicopter.

The U.S. makers market shares of the total free world helicopter production are shown in Table A-4. The data have been rounded to the nearest percentage point. Selected data are presented for ease of reading and the peak years' data are included. The very apparent trend is the declining market share of Bell, resulting in the declining U.S. market share. In 1982, foreign makers produced more than the U.S. makers for the first time. The Sikorsky share is increasing as a result of the production of the UH-60 Black Hawk.

Similar data for the European makers is shown in Table A-5. Again, the data have been rounded. Two trends are apparent, firstly the increase in the European market share over the last decade from about 30 percent to just over 50 percent, and, secondly and perhaps more significantly, the increase in the market share of Aerospatiale of France to over 20 percent of total free world production.

U.S. helicopter production is shown in Figure B-4 (Table A-6). The data shown in this figure varies from the data in Figure B-2, due in part to the different data source, and in part to the fact that it does not include foreign

military sales. What is significant, however, is the general trend indicating the vast production to support Vietnam in the mid 1960s, followed by a declining military production and an increasing civil percentage. Also apparent is the declining civil sales in 1981/82, due primarily to poor economic conditions.

U.S. helicopter production in dollars is shown in Figure B-5 (Table A-7). The correlation between Figure B-5 and Figure B-6 is good up until 1979. At this point, the dollar value of military deliveries increases despite a declining military unit production, reflecting the military requirement for a fewer number of more sophisticated and hence more expensive helicopters.

The U.S. manufacturers percentage of U.S. production is indicated in Figure B-6 in cumulative form (the data are presented in Table A-8 in absolute form). The early dominance of Sikorsky is apparent, with Bell rapidly gaining market share in the 1950s. Boeing-Vertol's contribution to the Korean conflict in the 1950s can be seen. The dominance of Bell and the emergence of Hughes in the mid 1960s Vietnam period is also apparent. In the early 1980s, Sikorsky, Hughes and Bell have emerged as the major forces in terms of unit production U.S. market share

Figures B-7 and B-8 (Tables A-9 and A-10) indicate the relative movements of U.S. imports and exports. The graphs show the general decline in civil helicopter sales in 1981

and 1982 (the 1983 and 1984 figures are estimates and forecasts respectively).

The data in Figures B-9 and B-10 (Tables A-11 and A-12) reveal the fact that Aerospatiale has the largest share of foreign imports. Europe now accounts for 50 percent of the free world production and Aerospatiale constitutes some 40 percent of that European market presence (Table A-6).

Figure B-11 (Table A-13) indicates that whilst all segments of the civil helicopter market have shown steady growth since the 1960s, the dominant growth segment has been the commercial helicopter. A contributing factor to this growth has been the boom in off-shore oil rig support, air ambulance, air taxi, news media gathering, and corporate/executive transport.

E. THE GROWTH OF THE EUROPEAN THREAT TO U.S. MARKETS

This chapter would not be complete without a discussion of the European intrusion into the U.S. civil market. Figure B-9 shows the growth of European helicopters imported into the United States. The degree of penetration by Aerospatiale of France has the most significance. This section will consider the growth of Aerospatiale.

In the period 1940-1945, the Focke-Achgelis Company in Northern Germany successfully produced helicopters but production was halted by the cessation of World War II. Other European efforts in Austria, Germany, France, and England

were similarly disbanded in 1945. Beginning in 1945, the French and English governments decided to promote new helicopter concepts. The French Government allocated funds to the principal French aeronautical companies to design and build rotary wing aircraft. In the period 1945 to 1952 the Societe Nationale de Construction Aeronautique du Sud-Est (SNCASE) evaluated the Focke-Achgelis technique, whilst the Societe Nationale de Construction Aeronautique du Sud-Ouest (SNCASO) became interested in the Doblhoff tip-jet technique. The Societe Nationale de Construction Aeronautique du Centre (SNCAC), the Breguet Company, the Societe Nationale de Construction Aeronautique du Nord (SNCAN), and the Societe Nationale de Construction du Sud-Est (SNCASE) all produced helicopters that flew during 1948, 1949, and 1950, but none passed through the testing stage. The results were disappointing and the SNCAC, Breguet, and the SNCAN companies decided to halt expenditures and abandon helicopters. In 1950, only SNCASE and SNCASO remained competitive (in France) to try and find more suitable techniques. [1:150]

In Britain, after some attention to autogiros, the Bristol Aeroplane Company produced the first functional European production helicopter, the Bristol Sycamore, of which 200 units were produced. The Westland Company became involved in building Sikorsky helicopters under license (first the S-51, then the S-55), before joining forces in 1959/60 with the rotary wing activities of the English firms,

Saunders-Roe, Bristol, and Fairey. SNCASE, prompted by events in Algeria, acquired a license for the Sikorsky S-55 in 1952 and the Sikorsky S-58 in 1956. Sales and maintenance contracts were signed by other French firms for Bell, Hiller, and Piasecki aircraft, as the Europeans recognized that the American products, being 5 to 10 years more advanced than the European technology, were dominating the market. They were joined by the Italian firm, Agusta, who bought a license for the Bell 47 in 1952. [1:151]

The period 1952-1959 marked the turning point of the European industry and saw the arrival of turbine helicopters, in a sequence of events that favoured the French industry, leading to that nation's dominance of the European makers.

Of the two main French firms, SNCASO moved towards tip jet helicopters, whilst SNCASE developed a Sikorsky type single main rotor helicopter. The design teams of the two firms were given the objective of producing light helicopters weighing less than 800 kilograms empty. The SNCASO approach led to the Djinn, which received French certification in 1957 and American certification in 1958. As mechanically driven helicopters improved, the advantages of the Djinn diminished, and it never achieved great success. In the meantime, SNCASE developed the three-seat piston engined Alouette I, which first flew in 1951. In 1953, it was decided to mass produce this helicopter but the advent of the turbine engine reversed this decision. In order to

achieve market success, it was decided to develop a new helicopter that would be competitive but superior in performance to existing light helicopters. It would be a five place helicopter, designed around the advantages of a turbine engine, and basic in design and uncomplicated (making it capable of being disassembled into sub-units to facilitate production, maintenance, and sales). These requirements led to the Alouette II that was first produced in 1956. Previously, the American firms of Kaman, Bell, and Sikorsky had all experimented with turbine power beginning in 1951, but they had only limited success. The secret of the success of the Alouette II lay in its sound design and ease of construction leading to decisive advantages in performance, safety, and maintenance [1:156]. This helicopter received French certification in 1957 and American certification in 1958. By the end of 1959, more than 300 Alouette II helicopters had been produced [3:157]. Total production through 1975 (the end of production) was 1307 units.

In 1957, SNCASO and SNCASE merged to become Sud-Aviation. This firm adopted a philosophy of continuous innovation and incremental improvement in order to improve the commercial position of the French industry. This approach has proved very successful, as reference to Figure B-12 will reveal. The graphs indicate sales, employment, and product introduction history for Aerospatiale. The planned expansion was emphasized by a new prototype every two or three years. [7:250]

The Alouette II was rapidly followed by the Alouette III which first flew in March, 1959. With seven seats, it had no competition. A further innovation was the use of a strongly "derated" engine (i.e., used below maximum power). This meant that the helicopter still had a lot of power available at maximum throttle at high altitude. Further, it was readily adaptable for rescue operations and ambulance operations [7:251]. The superiority of the Alouette III was demonstrated when the first French military orders were awarded to the company. Production amounted to almost 1400 units and continued until 1979 in France and 1981 in India and Romania (licensed production). Several product improvements were introduced during the life of the model.

In 1969, the company merged with Nord-Aviation, to become the Societe Nationale Industrielle Aerospatiale (or Aerospatiale). This year also marked the commencement of the first real intrusion into the American market, with the creation of Vought Helicopter Incorporated (VHI) by Ling-Temco-Vought, who desired to become a new helicopter manufacturer. They held production licenses for the light Alouette and Gazelle helicopters. These aircraft were successful and led to Aerospatiale buying the helicopter subsidiary from Ling-Temco-Vought and renaming it the Aerospatiale Helicopter Corporation (AHC). The acquisition included the entire staff and was able to capitalize on the tremendous early promotional work of the Alouette and Gazelle.

Today, the AHC is located in modern facilities in Grand Prairie, Texas. Deliveries in 1980 represented 20 percent of the North American commercial market. [7:249]

The Alouette III was rapidly followed by the Frelon (a three turbine naval helicopter) in 1959, the Super Frelon (a thirty place three turbine upgrade of the Frelon) in 1962, the SA-330 Puma (a French Army tactical helicopter that subsequently enjoyed considerable commercial success in Europe), the SA-340 (a high performance, five place, light helicopter that employed newly developed fibreglass blades) in 1968, and the SA-315 Lama in 1968. This was a combination of the light Alouette II airframe and the rotary parts of the more powerful Alouette III, especially designed for high altitude work and still remaining without real competition in this field.

The philosophy of modernization and improvement was further applied in the 1970s with the development of the AS-360 Dauphin (a modern Alouette III with increased performance and safety, decreased maintenance, and with ten seats). Aerospatiale recognized the market tendency towards twin engined safety, and upgraded the Dauphin to the AS-365C, for which commercial certification was received in 1978. A further model improvement led to a successful bid in a U.S. Coast Guard contract to modernize their fleet in 1979.

The Gazelle had been a successful military helicopter but its high performance made it relatively expensive, and

therefore, not competitive in the commercial field. Accordingly, Aerospatiale set about designing a new six seat light turbine helicopter with two prime objectives, reduction of production cost and reduction of operating cost [7:255].

The consequent AS-350 Ecureuil was produced in two versions, one for the European market (with a Turbomeca engine), and the AStar (specifically designed for the North American market (with the Lycoming LTS 101 American turbine).

Aerospatiale entered the medium weight market in 1981 with the upgraded and stretched AS-332 Super Puma, aimed at the emerging long distance off-shore oil rig support market [7:252].

As they had for the Dauphin, the engineers returned to the single engined Ecureuil AStar to transform it into a twin turbine craft. The AS-335 TwinStar first flew in 1979. A further upgrade of the TwinStar was certified in America in 1981. The TwinStar has proved most popular in the corporate and emergency medical services (EMS) markets, with eleven being employed in an EMS role by the end of 1983 [11:34]. This aircraft competes with the MBB Bo-105 and the Agusta 109 in the North American light twin market. Bell is preparing a new model 400 TwinRanger, which will be made in Canada and which is heralded as the first in a new line of Bell single and twin light helicopters designed to combat the French invasion.

Leaving aside the Gazelle and the Lama, all the other Aerospatiale helicopters are very modern and constitute a very aggressive entry into the world and U.S. markets. Without counting aircraft manufactured under license, Aerospatiale Helicopter Division had sold (by the end of 1981), almost 7000 helicopters of all types to 520 customers spread over 100 countries [7:256]. Reference to Figure B-9 quite clearly indicates the very successful results Aerospatiale has achieved in the North American market in the last five years.

Despite the fact that Aerospatiale is the primary contributor to the European penetration of the U.S. market, the potential impact of the other European makers should not be minimized. MBB has two subsidiaries in North America and has become the first European manufacturer to plan production operations in North America, with its announced intention of producing the MBB Bo-105 in Canada for distribution through its MBB Helicopter Corporation (MBBHC) subsidiary in West Chester, Pennsylvania.

Agusta has also targeted the North American corporate and public service markets with the Agusta 109 light twin eight place helicopter.

Westland Helicopter, of England, has aimed a development of the successful military Lynx series, the Westland 30, at the American market (commuter, ambulance, off-shore, executive, and cargo roles), with three helicopters being in

interline airline service in Los Angeles and two in New York. They are also developing the EH-101 (for military and civil markets), in collaboration with Agusta of Italy.

In summary, the European helicopter industry emerged after World War II. The European companies had experimented on their own, and all had contact with American manufacturers in one way or another, ranging from design help to outright purchases of licenses to manufacture. Once begun, progress in the European helicopter industry was rapid. Today, according to the Aerospace Industries Association of America's November, 1983 report, "The U.S. Helicopter Industry", European manufacturers account for over 50 percent of free world production, and Aerospatiale accounts for about half of that share. Many helicopters, American or foreign, have both military and civil versions. While it appears that the military/civil divergence is increasing, some of the newest European designs are conceived with both civil and military applications in mind. [12:71]

IV. COMPETITORS IN THE HELICOPTER INDUSTRY

A. INTRODUCTION

In its approximately forty year history, the helicopter industry has spawned many participants. The successful firms have generally survived through a combination of fortuitous good luck and winning the right military competitions, although in some cases, a firm has achieved great success with a product line or concept after losing the contest it was entered in. The survivors, at least those who dominate the market, have one factor in common; they are all part of a larger corporate or national organization.

The American participants have produced over two-thirds of the free-world's helicopters over the last twenty years. They are: Bell Helicopter Textron Inc., a subsidiary of Textron Inc.; Boeing-Vertol Company, a division of the Boeing Company; Hughes Helicopters Inc., a subsidiary of the McDonnell Douglas Corporation; and Sikorsky Aircraft, a division of United Technologies Corporation. Other U.S. manufacturers include Hynes Helicopters Inc., the Enstrom Corporation, Hiller Aviation Inc. (recently acquired by Rogerson Helicopters after running into financial difficulties), the Kaman Corporation, and Robinson Helicopter Company Inc.

The balance of the free-world's helicopters have been mainly manufactured by the four major European makers, namely:

Societe Nationale Industrielle Aerospatiale of France; Messerschmit-Boelkow-Blohm (MBB) of West Germany; the Agusta Group of Italy; and Westland Helicopters of the United Kingdom.

There are also several foreign makers who are predominately involved in licensed production of helicopters designed by one of the eight major manufacturers. These firms include Nurtanio of Indonesia, Helibras of Brazil, and Kawasaki, Fuji and Mitsubishi of Japan.

The European and foreign firms, in general, gained their entry to the industry through licensed production of U.S. designs, buying design, manufacturing, production, and technical expertise.

This chapter will provide a brief profile of each of the major competitors, as well as some comment on the minor manufacturers, Soviet producers, and some competitors who failed.

B. U.S. COMPETITORS

1. Sikorsky Aircraft

Igor Sikorsky is considered by many to be the father of the helicopter industry. He initially experimented, unsuccessfully, with helicopter designs in his native Russia in 1909 and 1910. He was constrained by the lack of a suitable propulsion unit and surrendered his interest in helicopters for a number of years. He came to America following the

Communist Revolution in Russia in 1917 and founded his own company, successfully producing fixed wing aircraft for a number of years. In 1929, the financially troubled Sikorsky Aviation Corporation became first a subsidiary of and then a division of United Aircraft, now the United Technologies Corporation.

In 1938, after 10 years of research, he received the go-ahead to proceed with the design and construction of a direct lift aircraft. The subsequent first flight of the VS-300 on September 14, 1939, marked the birth of the helicopter industry. By 1941, Sikorsky aircraft were in service with Army and Naval Air Forces around the world. No other U.S. manufacturers then existed.

His early designs established the Sikorsky design preference for a single main rotor/single tail rotor concept and a penchant for a "bigger is better" philosophy. An examination of the Sikorsky product line development over the years will reveal that these philosophies have remained with Sikorsky.

As with most helicopter manufacturers, Sikorsky has approached commercial helicopter design by adapting designs developed under military contracts. Following World War II, Sikorsky developed helicopters aimed at both the military and civil markets. These included the S-51, a derivative of the early military VS-327 (military designation R-5), which achieved quantity production of about 380 units in the late

1940s,/early 1950s, and the S-55 (military designation H-19), the first troop carrier, which achieved a production run of approximately 1800 units through the 1950s, and the S-58 (military designation H-34) that reached a production total of over 2200 units.

The late 1950s saw Sikorsky take advantage of the available technology, and they entered the turbine powered helicopter field with the S-61 (SH-3), S-64 (CH-54A/B) and S-65 (CH53A/D). These aircraft became progressively larger as Sikorsky gained more design and production experience. Over 1600 of these aircraft were built during the 1960s and they saw service in a wide variety of civil and military roles. The S-61 remains in military service in substantial numbers around the world and its civil variants were and still are highly successful in the emerging civil market at that time; i.e., off-shore oil rig support.

In the early 1970s, Sikorsky went through some difficult times as their long running production lines began to dry up, without the arrival of new production programs. Sikorsky applied considerable company effort to winning the Army Utility Tactical Transport Aircraft System (UTTAS) competition with its Black Hawk entry. The program was won in 1976 and has led to successful access to other military derivative programs (Navy Seahawk and Air Force Night Hawk). It also provided opportunity to develop a commercial derivative and an overseas military version for foreign military sales.

The successful S-65 program has also led to success in the Navy and Marine Corps requirement for heavy-lift helicopters with the triple turbined, 70,000 lb. CH-53E Super Stallion, now the free world's largest helicopter.

Also in the 1970s, Sikorsky broke with tradition and developed the S-76 purely for the commercial market (primarily for the corporate, executive and oil rig support market). This aircraft was sized between its perceived competition, the Bell range of light helicopters and the medium-lift helicopters produced by Boeing-Vertol. This helicopter has not been as successful as Sikorsky would have liked, due in part to the general decline in civil helicopter sales in the early 1980s.

Sikorsky has licensed Agusta, Westland, and Mitsubishi for overseas production of U.S. designs. In history up to September 14, 1979, Sikorsky had produced a total of 5545 helicopters, with an additional 1672 units being produced by foreign licensees.

Sikorsky has always been actively involved in ongoing research and development, devoting considerable effort to the Advancing Blade Concept (ABC), believing it to be the answer to developing high speed requirements. Other endeavors include the Advanced Composite Airframe Program (ACAP), an Army funded program to develop a lighter all composite airframe, and the Sikorsky-developed Rotor Systems Research Aircraft (RSRA), a joint NASA/Army program to develop new technology rotor systems.

In terms of new military programs, Sikorsky will be an entrant in the major new helicopter program, the Army new Light Helicopter (LHX) program that promises substantial production orders through the year 2000. Sikorsky sees this program as a successor to the Black Hawk program in terms of keeping its production shop floor busy.

2. Bell Helicopter Textron Inc.

Larry Bell launched the Bell Aircraft Corporation on July 10, 1935, with 56 employees. His company achieved success in the war years, producing many fighters and bombers for the war effort. By 1944, the company employed more than 50,000 people in four plants.

At the beginning of the war, Bell had hired Arthur Young, an inventive engineer who was very interested in helicopters. Young and his small staff were established in a small garage in Buffalo, completely divorced from the war efforts of the company. The Bell helicopter wasn't quite ready at the end of the war but in September, 1945, Bell announced that his company would enter the helicopter field. His foresight paid off because after V-J day in August 1945, almost all the company's business was cancelled. Bell's business base dropped from \$317 million in 1944 to \$11 million in 1946 and the workforce dropped to 2920.

Bell was confident of his helicopter development, and, anticipating significant military and commercial applications, decided to build 500 units without orders. Commercial

sales were slow, however, and it appeared that Bell might have made a mistake. In the period to 1950, Bell only sold 175 helicopters. The Korean War intervened, however, and the Army urgently required a large number of helicopters. The advanced Sikorsky S-52 was not in a production-ready stage, and Bell was able to win the competition on delivery schedule with its now famous Bell 47 production line. This win put Bell on the map, with the Bell 47 being phased out of production in 1974 after a cumulative production run of 6263 units, with about fifty percent of these going to military customers.

The next major event for Bell was the winning of a design competition for the development of a utility helicopter suitable for medevac, general utility and training purposes. Bell won this competition in 1959 with the ubiquitous UH-1 "Huey", the first production beneficiary of the newly developed gas turbine engine. This win led to a production run of over 12,000 units of the various derivatives, marketed as the UH-1 (military) and the Models 204, 205, 212, 214 and 412 (civil).

In 1962, the U.S. Army's Tactical Mobility Requirements Board issued a report that officially endorsed, for the first time, the use of armed helicopters. The war in Vietnam demonstrated this truth, and the armed UH-1 Huey was pressed into service as an interim measure. Bell was initially eliminated from the requirements design competition in early

1965, but with a private-venture development of the Bell 209 was able to win the subsequent production competition. That aircraft was born as the AH-1G Cobra. It also enjoyed a very long production run of 1775 units and will remain in service (product improved) until the year 2000.

Bell's business in recent times has been less promising. Whilst continuing to enjoy civil success with their light derivatives, Bell entered and lost a number of military competitions that provided good opportunities for competitors to steal some of Bell's military business. These were the Army Light Observation Helicopter (LOH) competition in 1961, lost to the Hughes OH-6 (subsequently the very successful Hughes civil 5-0); the Army Advanced Attack Helicopter (AAH) in 1973-76 to the Hughes AH-64 Apache; and the Army Utility Tactical Transport Aircraft System (UTTAS) to replace Bell's Huey in 1976 to the Sikorsky UH-60 Black Hawk.

These were significant losses to Bell, who is now under considerable pressure for continued survival to win either or both of the two major current military programs, the Joint Services Vertical Lift Aircraft (JVX), and the Army's Light Helicopter Program (LHX). Bell has been kept alive in the military business by winning the recent Army Helicopter Improvement Program (AHIP) against Hughes to develop a near term scout helicopter. Bell was also selected as one of two winners (with Sikorsky) to participate in the Advanced Composite Airframe Program (ACAP).

Perhaps Bell's most promising military work is its teaming arrangement with Boeing-Vertol to participate in the development of the JVX. Whilst the team is the only one under contract for the development phase, it appears that the government intention is to compete the two firms head to head for follow-on production after initial production. Bell has a head start in this program, having developed its tilt-wing technology in an earlier (1951) Army-Air Force Program that funded the development of the experimental XV-3 tilt-wing convertiplane in 1955. This led to the XV-15 occurring in 1977 (under joint Army/NASA sponsorship).

Bell Helicopter has licensing arrangements with Agusta of Italy; Mitsui of Japan and Nurtanio of Indonesia.

Bell Helicopter Corporation was founded as a wholly owned subsidiary of the Bell Aircraft Corporation in 1957. On July 5, 1960, Textron Inc. purchased the defense activities of Bell Aircraft Corporation, setting up Bell Aerospace Corporation as a wholly-owned subsidiary with three operating divisions, the Bell Helicopter Company, Bell Aerosystems Company, and the Hydraulic Research and Manufacturing Company. Bell established itself as Textron's largest division and in January, 1982, the company status was changed to Bell Helicopter Textron Inc., a wholly owned subsidiary of Textron Inc.

Bell's philosophy throughout the years has been to build helicopters for the light and intermediate market segments, relying primarily on military aircraft with civil

adaptability. A significant effort has been applied to developing civil derivatives that can be competitive regarding price and operating costs, i.e., to build aircraft that operators can make money with.

Bell, like Sikorsky, has recently developed a pure commercial model, the Bell 222, also for the corporate, executive and oil market. It is somewhat smaller than the Sikorsky S-76, but its sales have not been impressive, again due in part to the declining civil market in the early 1980s.

One of Bell's early competitive advantages was its extremely simple and inexpensive two-bladed see-saw rotor systems that helped to keep price and operating costs down. It would appear that Bell was reluctant to progress from this technology even though their customers wanted the extra advantages of a four-bladed articulated rotor system. This reluctance prevented them from capturing market share that they might otherwise have obtained.

3. Boeing-Vertol

P-V Engineering Forum Corporation was incorporated by Frank Piasecki in 1943. This organization designed and built the PV-2, which first flew on April 11, 1943. It was the second U.S. helicopter to be flown publicly. The company's second aircraft was the PV-3, the world's first practical tandem rotor machine that led to production of the "flying banana" (the Navy HRP-1) in 1947. This success was a result of a private-venture by Piasecki to build a demonstrator

(the XHRP-X) in 1945. In 1946 the company changed its name to the Piasecki Helicopter Corporation. The HRP-1 was improved to the HRP-2 which was sold to the Air Force and the Army as the H-21 (Workhorse and Shawnee).

This aircraft saw considerable service in Vietnam and was used by many foreign military forces. The original armed helicopter trials were carried out with the Shawnee but the concept never developed for Boeing-Vertol, the armed helicopter battle being won by Bell with its armed "Huey" and later the Cobra.

Piasecki also entered the Navy market in 1949 with its smaller PV-14/18 (HUP Retriever or H-25 Army Mule). This aircraft also had the traditional tandem rotor and had a production run of about 270, with some of the Navy aircraft being fitted with dipping sonar.

In 1950, Piasecki was contracted by the U.S. Air Force to develop a long range rescue helicopter. The subsequent helicopter, then the world's largest, was unsuccessful although the second of the two prototypes was credited with being the world's first twin engined turbine helicopter. The program was cancelled in 1954 after the crash of this prototype.

In 1956, Piasecki adopted the name Vertol, and Boeing Aircraft acquired Vertol in 1960 when it became the Vertol division of the Boeing Company.

Piasecki (or Vertol) conducted a private-venture into a high speed compound helicopter in 1962, resulting in some Army/Navy sponsorship for modifications to the 16H-1 Pathfinder to achieve a speed of 230 mph. It successfully flew at 225 mph but did not enter production.

Boeing-Vertol continued the tradition of tandem rotor design, developing the Model 107 as the H-46 for the Army as a medium lift transport. This aircraft achieved quantity production and entered service in 1962, serving with the Marine Corps and the U.S. Navy and has been licensed overseas to Kawasaki as the KV-107. Boeing-Vertol production was 666 machines when production ended in 1971.

The very successful Boeing-Vertol 114 (CH-47) followed, entering service in 1962 and becoming the western world's standard for medium lift helicopters. It is flown worldwide and continues to be modified and updated. This aircraft also saw service during Vietnam when four were modified as "heavy gunships", as another forerunner of the armed attack helicopter requirement.

The Boeing-Vertol YUH-61A competed against Sikorsky for the Army Utility Tactical Transport Aircraft System (UTTAS) program, losing the competition on 23 December, 1976. Boeing-Vertol then entered a modification of the YUH-61A in the Navy's LAMPS III competition against a Sikorsky modification of its UH-60B UTTAS winner and a Westland/Aerospatiale

modification of their Lynx. The paper competition was lost to the navalized Sikorsky SH-60B on September 1, 1977.

In November 1970, the U.S. Army requested industry proposals for a heavy lift helicopter (HLH) able to carry a load of 20 tons for a radius of 20 nautical miles. Boeing-Vertol was selected to develop the concept, and built the model 347 helicopter, based on their CH-47 design. The subsequent development contract was cancelled in October, 1974, when the program was experiencing high costs and when the Navy and Marine Corps decided to pursue the Sikorsky CH-53E for their heavy lift requirements.

The prototype was never completed, although recent events indicate a re-awakening of interest, with Boeing-Vertol being contracted to complete the development of the prototype as a demonstrator of the heavy lift concept.

Commercially, Boeing-Vertol entered the market initially with the Piasecki V-44 in 1956. This was replaced with the turbine powered Model 107 (the commercial CH-47) in 1958. The Boeing-Vertol Chinook (CH-47) that first entered service in 1962 and has sold over 1000 units worldwide was developed commercially as the Model 234 Chinook, primarily to service the long range oil rig market.

The bulk of Boeing-Vertol's current business is modification of the CH-47 Chinook fleet, although the company is working on research projects such as the heavy lift helicopter, the Army/NASA X-wing project, and the private-

venture high speed helicopter, the Model 360. They are also involved, as a team member, with Bell Helicopter, in the Navy/Marine Corps Joint Services Vertical Lift Aircraft program.

Boeing-Vertol has licensed Kawasaki of Japan for Model 107 production, Agusta of Italy for Chinook production and itself had a license to market the German MBB Bo-105 in Canada, Mexico and the United States until withdrawing from that arrangement in 1978. The rotor system for Boeing-Vertol's UTTAS candidate was adapted from the MBB Bo-105, in a unique Europe to United States licensed technology transfer.

4. Hughes Helicopters Inc.

Hughes Helicopters traces its origins to February 13, 1934, when Howard Hughes Jr. launched the Hughes Tool Company Aircraft Division. Howard Hughes had a passion for aviation and the aircraft division was essentially his hobby shop. At the end of the war, when nearly all military programs were cancelled, Hughes kept his California team busy making proposals for new aircraft and missiles.

In 1946, Kellett Aircraft of Philadelphia was involved in developing the XH-17, a derivative of a European jet powered rotor machine. The advantage of this concept was that no heavy transmission was needed, the rotor being driven by compressed air feeding kerosene burning nozzles at the rotor tips, much like a lawn sprinkler. This made it particularly attractive for very large heavy lift helicopters.

The XH-17 had a rotor diameter of 130 feet and was to be capable of lifting 40,000 lbs. gross weight.

By 1949, with design completed and fabrication started, Kellet was in financial difficulties. Hughes, ever on the lookout for new work and an aviation challenge, purchased the XH-17 project and moved it to the Hughes Aircraft Company plant at Culver City, California. The XH-17 first flew in October, 1952 and the flight test program ran for three years. Whilst the program added to Hughes technology base, the advent of the Korean War shifted the emphasis to large numbers of small helicopters rather than a few very large helicopters.

Hughes then bought the rights to the very simple design of a three bladed rotor system developed by a neighboring firm, the McCulloch Motor Corporation, and focused on the very light range of helicopters. By 1956, Hughes had developed the Hughes 269, designed as a light, two place commercial helicopter. This company program led to the very successful Hughes 300 commercial helicopter.

In mid 1964 the U.S. Army selected the Hughes 269A as the TH-55A Osage light training and utility helicopter. A total of 2738 units of this model were built, with nearly 800 being delivered to the Army as the TH-55A. Hughes has now licensed the Schweizer Aircraft Corporation to produce the Model 300.

In the early 1960s the U.S. Army held a design competition for a turbine powered light observation helicopter. Hughes won the competition with its OH-6A Cayuse against proposals from Bell and Hiller. The Cayuse entered service in 1966 and about 1450 units were produced for military service, the aircraft being extensively used in the Vietnam conflict. Simultaneously, Hughes developed a commercial derivative, the Model 500 that has also become an extremely successful entry into a wide range of civil applications. The product line, including military and civil derivatives, had sold some 3600 units by 1983.

The philosophy adopted by Hughes in both the Model 300 and Model 500 was to "simplify and add lightness" and to design for ease of maintenance and reduced operating costs.

Hughes has developed both the 300 and 500 models as overseas military versions, using their position as the free world leader in medium calibre cannon production to advantage.

Through a long sequence of events, Hughes won the Army competition for the Advanced Attack Helicopter in 1976 in a fly-off between its AH-64 Apache and the Bell YAH-63. These events followed the failure of the Lockheed AH-56A Cheyenne in the Army's Advanced Aerial Fire Support System (AAFSS) program in 1972. This success has led to production contracts for the Apache.

As a result Hughes is in the process of moving its operations to Mesa, Arizona, where it has built a new plant. Hughes has now been acquired by the McDonnell Douglas Corporation as a wholly owned subsidiary. With the corporate strength of McDonnell Douglas, Hughes will become a formidable competitor in the Army Light Helicopter program (the LHX) with its unique no tail rotor concept (NOTAR).

C. EUROPEAN COMPETITORS

1. Aerospatiale Helicopter Corporation

After World War II, the French Air Ministry, observing that France was lagging behind the U.S. in helicopter development, signed several contracts for helicopter design with the following companies: SNCASE, SNCAN, SNCAC, SNCASO, and Breguet. However, at the beginning of 1954, no French helicopters were being produced, with helicopter requirements being satisfied by the imports of the Bell 47, Hiller 360, Piasecki HUP-2 and the Sikorsky S-55. The S-55 was being produced by SNCASE under license. The Air Ministry determined that, in order to establish a niche in the industry, it was necessary to develop a helicopter that would not clash head to head with the American products. This led to the turbine powered Alouette II which first flew in March, 1955. This aircraft broke the international altitude record and was especially suited to mountain work. As a five seater, it occupied the segment between the three seat Bell 47 and Hiller 360 helicopters and the ten seat Sikorsky S-55.

In January, 1957, SNCASO and SNCASE merged to become Sud-Aviation. Under Sud-Aviation, production shifted to the Alouette III in 1959 (especially designed as a seven seater for high altitude work). The Alouette product line was a commercial success.

The parent company of Aerospatiale Helicopter Division (AHD), Societe Nationale Industrielle Aerospatiale (SNIA), was formed in January, 1970, by a merger of three government-owned companies, Nord Aviation (fixed wing aircraft and tactical missiles), Sud-Aviation (fixed wing aircraft and helicopters), and SEREB (space engineering). Thus, Aerospatiale is and always has been owned by the French Government. Up until this time, Sud-Aviation had always concentrated on light helicopters. In order to penetrate the medium and heavy markets, Sud purchased Sikorsky technology, leading to the Puma (twin engined 8000 lb. tactical transport), and the Super Frelon (three engined 15,000 lb. antisubmarine, passenger and cargo helicopter). The Super Frelon is no longer in production but about 100 remain in a variety of civil and military uses. The Puma also stopped production in about 1980, but is still in wide use. It has led to the multi-purpose civil and military Super Puma now in use in fourteen countries. The Super Puma competes head to head with the Sikorsky UH-60 Black Hawk for troop transport contracts. Aerospatiale is unique in both Europe and the U.S.

in that it offers a range of light to heavy helicopters, in civil and military variants, in simultaneous production.

Aerospatiale formed an arrangement with Ling-Temco-Vought (LTV) in the United States in the early 1970s in order to market Aerospatiale helicopters in the U.S., Canada and Mexico. This arrangement was disastrous in the beginning, with the main deficiencies being product support and inadequate customer credit investigation. In about 1974, management changes were initiated, and the name was changed from Vought Helicopters Inc., (VHI), to Aerospatiale Helicopter Corporation (AHC). The need to develop customer confidence in product support was emphasized and the result has been a significant penetration of the U.S. market by AHC.

Aerospatiale has been a consistent investor in research and development, allocating about 9 percent of sales to innovative technologies, particularly in the use of composites.

Aerospatiale has a wide range of licensing arrangements, including India (Alouette III and Puma), Yugoslavia (Gazelle), U.K. (Gazelle, Puma and Lynx co-production), Indonesia (Puma and Super Puma), Brazil (Lama and Ecureuil), and China (SA-365N Dauphin 2).

2. Westland Helicopters Ltd.

The British company, Westland Aircraft Ltd., (now Westland plc), was formed in July, 1935, to take over the

aircraft branch of Petters Ltd., known previously as the Westland Aircraft Works, which had been engaged in aircraft design and construction since 1915. The Westland story is the familiar one of a traditional European aviation company moving into helicopters after World War II. Unlike its European helicopter contemporaries, Westland has also made a large effort in the hovercraft business so that Westland, with about 7,400 employees, is organized with British Hovercraft Corporation's 1,500 employees into the Helicopter and Hovercraft Group of Westland plc [12:77].

Westland is now one of Europe's leading helicopter manufacturers, but from 1915 up to 1946, the company mainly produced fixed wing aircraft. It entered the helicopter industry in 1947, by acquiring a license to build the Sikorsky S-51, which Westland manufactured as the Dragonfly. This decision was taken after Westland concluded that the future lay in helicopters. The technical association with Sikorsky has continued since that decision to concentrate on the design, development and construction of helicopters [13:285]. Westland's several other versions of the S-51 were produced for the Royal Air Force, Royal Navy, civil operators, and, eventually, foreign military and civil customers. Subsequent and current Westland designs are heavily dependent on collaboration with other companies [12:81].

In addition to U.S. technology, Westland received domestic design technology transfers through its government-

enforced merger with other British helicopter firms in 1960. Two of these, Bristol and Saunders-Roe, brought with them existing programs already in production, and all brought engineering expertise that led to the development of Westland's first domestic model, the WG-13 Lynx. Two earlier British designed models, the Wasp and the Scout, had been produced by Saunders-Roe prior to the merger. This aircraft was later included as part of a collaborative program with Aerospatiale that also covered that firm's SA-341 Gazelle and SA-330 Puma models.

Westland's links with Sikorsky were strengthened by the license to produce the Sikorsky S-61 Sea King, originally concluded in 1959. The Sea King still constituted some 20 percent of Westland's production output in 1980 [14:15], although Westland has made considerable changes in the power plant and specialized equipment, initially to meet a Royal Navy requirement for an advanced antisubmarine helicopter with prolonged endurance. The aircraft was also targeted at secondary roles such as search and rescue, tactical troop transport, casualty evacuation, cargo carrying and long range self-ferry [13:285]. A total of 204 Sea Kings and 32 of its tactical transport version, the Commando, have been delivered to the U.K., West Germany, India, Norway, Pakistan, Egypt, Belgium, Saudi Arabia, and Australia [12:81].

Westland's Lynx was one of the first products of the European multinational helicopter co-operative ventures.

Westland was the design leader and Aerospatiale the co-producer. The arrangement was confirmed in 1968 and the first aircraft flew in 1971. The aircraft was targeted at the intermediate weight range (7,000 to 15,000 lbs.) utility and naval roles. Lynx is a highly successful military program with approximately 70 percent of the production being performed by Westland and 30 percent by Aerospatiale [8:93]. Westland offered the Lynx to the U.S. Navy in the LAMPS II antisubmarine helicopter program competition before that program was cancelled. An improved Lynx was also offered in the U.S. Navy LAMPS III competition against the Boeing-Vertol and Sikorsky bids. The competition was eventually won by Sikorsky in 1977 with its Black Hawk derivative, the SH-60B Seahawk.

From the successful Lynx program (more than 310 unit sales to the U.K., the Netherlands, Qatar, Denmark, Norway, West Germany, and Nigeria) emerged a civil derivative, the Westland 30 (which retains 85 percent of the proven Lynx). The Westland 30 is an intermediate weight (12,000 lbs. plus) with 19 places, targeted to compete with the Sikorsky S-76, both worldwide and in the U.S. and the Aerospatiale SA-330 Puma. The Westland 30 was developed after Westland decided, in 1978, that all the military Lynx needed to become successful commercially was bigger internal volume. The subsequent derivative is aimed at ambulance, off-shore, VIP/executive and cargo versions [12:81].

The Westland 30 aircraft are in service in the U.S. with Airspur Helicopters Inc. (a southern California interline airline) and Omniflight Helicopter Services of New Jersey (one for Pan American as an inter-airport service and one as a Westland demonstrator).

Westland is a publicly owned company, with head offices at Yeovil, Somerset, England, and receives the support of its government through military development programs and through government grants for international co-development programs.

For the future, Westland is developing the Lynx 3, a Lynx derivative dedicated to the anti-tank military helicopter market, although a follow-on naval series is also envisioned. First flight for the Lynx 3 is scheduled for 1985/1986.

Westland had a good year in 1983, with orders for the year totalling about \$562 million, compared to \$194 million for 1982. This business included orders for 34 Sea Kings (Britain and India), 12 Lynx, and 2 Westland 30s. Deliveries for the year included 11 Sea Kings, 33 Lynxs, 5 Westland 30s and 22 Gazelles.

As a not insignificant footnote, Westland, in 1983, established Westland Inc., as its U.S. office in Crystal City, Virginia, completing the formal entry into the U.S. of official company branches of all four European helicopter manufacturers [12:81].

3. Messerschmidtt-Boelkow-Blohm (MBB)

Willy Messerschmidtt formed his aircraft company in 1923 in plenty of time to deliver the ME-109 of World War II fame. A former Messerschmidtt employee, Dr. Ludwig Boelkow, later founded his own company, developing, in 1964, a hingeless rotor system with fibreglass rotor blades which led to the prototype of the MBB Bo-105 in 1967. In 1968, Boelkow and Messerschmidtt merged to become MB, and in 1969, MB merged with Blohm's Hamburger Flugzenbau to become MBB, thus making MBB the largest aerospace concern in Germany with about 38,000 employees, of which about 3000 are in helicopter activities [12:75].

The ownership of MBB is complex. It is a private firm in organization, its stock not being traded on the stock exchange. Stockholders include a variety of German banking interests, the Messerschmidtt Foundation, the State of Bavaria, a German holding company, and an industrial holding company that includes Aerospatiale of France. Of the total, 58 percent of shares is held by private industry [12:76].

The MBB series of helicopters began with the Bo-102, a non-flying trainer machine for the West German Army Air Force in 1957. This was followed by the Bo-103, which reached prototype flying stage in 1961, but did not go into production, owing to the limited interest in single seat helicopters, although the development gave MBB valuable experience in the construction of fibreglass blades [15:95].

Using this experience, the Boelkow development team commenced work on a hingeless rotor system in 1961. The initial study was for a two seat agricultural helicopter (designated the Bo-104), but this soon gave way to the five seat Bo-105, which incorporated the technological advantages of the hingeless rotor system and was the world's first light helicopter to be powered by twin turbines. These factors gave the Bo-105 real competitive potential. Sponsorship from the German Federal Ministries of Economics and Defense (loans to be fully repayable upon commercial success) was obtained, and work on the world's first light twin turbine engined helicopter commenced [15:97].

The Bo-105 was developed with adaptability and commercial use objectives, being certified to enter the American market in April, 1970. In 1974, it was selected by the German government as a light observation helicopter and a year later won approval as Germany's first generation anti-tank helicopter, designated the PAH-1.

The success of this aircraft in the international civil market can be attributed to its twin engined flight safety (it is marketed as the "twin jet"), reliability and its multi-purpose concept. More than 50 optional kits are available, making it readily convertible to off-shore oil support, police and rescue missions, executive transport and utility missions [15:98].

Through 1983, MBB had produced 649 Bo-105 civil variants, 189 Bo-105 VBH Army light observation helicopters, and 152 Bo-105 PAH-1 helicopters, making it a successful helicopter by any standards. Further development is planned to widen its market applicability, particularly powerplant development to increase its high altitude, hot temperature use.

A milestone in MBB's helicopter history was established in 1983 with the market introduction of the MBB/Kawasaki BK-117, a twin jet multi-purpose helicopter at the top end of the light helicopter range (about 6,300 lbs.). This was the result of a joint development venture which had originally involved Boeing-Vertol, who withdrew from discussions in 1975. From the outset, MBB and Kawasaki Helicopters Inc. (KHI) agreed on a multi-purpose concept and both contributed technical knowledge. Production is by the single source method, whereby each company makes the parts of its own design, and then exchanges parts to supply parallel production lines (one at MBB and one at KHI in Japan). The aircraft is designed for maximum market appeal and is certified throughout most of the western world for a wide range of civil uses (including that of passenger carriage in scheduled airline service). The BK-117 offers more usable, unobstructed space than any other helicopter in its class and can carry 11 passengers in its high density configuration [15:99]. Again, a wide range of optional equipment kits is offered to suit a broad spectrum of missions.

MBBs' interests in the U.S. were handled by Boeing-Vertol from 1972 until 1978 and during that time 68 Bo-105s were delivered to American customers. Boeing-Vertol's withdrawal from this arrangement in 1978 led to the formation, in 1979, of a wholly owned subsidiary, MBB Helicopter Corporation (MBBHC), in West Chester, Pennsylvania. MBBHC maintains a complete inventory of spares and exchange components and claims to be able to fill 98 percent of parts requests on the same day. Strong customer support is provided through a network of regional technical representatives, service stations and component repair centers. MBB's aggressive entry into North America continued in May, 1984, with the incorporation in Canada of another MBB subsidiary, 95 percent owned by MBB and 5 percent by Fleet Aerospace Corporation. Uniquely, and perhaps ominously for the U.S. helicopter industry, this subsidiary plans to be the first European firm to manufacture helicopters (the Bo-105) in North America [12:76]. This firm will not, however, compete with MBBHC, but will complement it, supplying Bo-105s to MBBHCs' U.S. customers as needed.

Meanwhile, in Europe, a long period of indecision came to an end on May 29, 1984, when the Ministers of Defense for Germany and France signed a Memorandum of Understanding that gives "systems leadership" responsibility to MBB and "co-contractor" responsibility to Aerospatiale for the production of the second generation Franco-German PAH-2

dedicated anti-tank helicopter. The two companies agreed to set up a joint company, Eurocopter, headquartered in Paris, to manage the program, which is expected to produce about 400 helicopters for both companies. The co-operation program consists of one basic design to satisfy the three variant requirements (French scout, French anti-tank and German anti-tank). Deliveries should commence in about 1992 [12:82].

MBBs' helicopter sales in 1981 amounted to \$152 million, whilst sales for 1982 were \$193 million. Total worldwide sales of the Bo-105 are about 1040 (through September, 1984), of which 156 have been sold in North America. MBB has determined that it will penetrate the North American market and is emphasizing its product support and distribution, its products technical attributes, twin engined safety and wide ranging civil adaptability to enhance its market share prospects.

4. The Agusta Group

Giovanni Agusta commenced his interest in aviation in 1907 when his efforts centered around the development of a novel biplane design. During the early 1920s, the firm specialized in fixed wing ultra light aircraft and sailplanes, as well as developing a solid reputation as a subcontractor for other manufacturers as a result of good quality work at its plant at Casina Costa, Italy [16:67].

Giovanni Agusta died in an accident in 1927, but his family continued to operate the business. The firm matured, and by 1951 was producing fixed wing aircraft (such as the CP-110, a four place, 170 mph aircraft) that were considered to be state-of-the-art at that time.

Domenico Agusta, the then president of Construzioni Aeronautiche Giovanni Agusta, brought helicopters into the company's business portfolio in 1952 when he acquired a license from the Bell Helicopter Company to produce the Bell Model 47. The terms of the license included the right to make Bell Model 47G parts for the European market. The total production of the Bell 47 reached over 600 for the period 1955 to 1973, when it ceased Agusta production.

By 1961, Agusta had commenced licensed production of its first turbine aircraft, the AB-204, again under license from Bell. This licensed version of the successful Bell-204 was followed by licensed production of the Bell-205 in 1965, the Bell-206 Jet Ranger in 1966, and the legendary UH-1 series, the Bell 212. The AB-206 Jet Ranger has been produced in numbers exceeding 850 from 1967 to the present time [12:76].

Similar licensing agreements with Sikorsky and Boeing-Vertol brought licensed production of the Sikorsky S-61, SH-3D, HH-3F models and the Boeing-Vertol CH-47C to the Agusta plant in the period from 1967 to 1970 [16:67].

Although all the four major European manufacturers received American technology transfer, it can be seen that Agusta carried the concept further than the others.

The first indigenously designed helicopter to be produced was the A-101G. It was a three engined (turbine) heavy lift transport helicopter designed for the Italian Armed Forces. The helicopter first flew in October, 1964, but never entered production, although three prototypes were built and subsequently tested by the Italian Air Force.

[8:97]

The Agusta A-106 was a single seat light ASW helicopter that was produced in small numbers for the Italian Navy. It was an original Agusta design, taking many design features from the earlier piston engined Agusta experimental helicopters (the A-103 and the A-104). Turbine powered, it first flew in 1965 and was introduced to the market in 1969. Marketing efforts failed, the helicopter being one of the few single seat helicopters ever to enter service, and the 23 ASW variants built for the Italian Navy constituted the total production [8:98].

Agusta used the many years of licensed production and indigenous design experience to develop the Agusta A-109 Hirundo helicopter. This is a high speed, twin turbined, eight place helicopter that competes more than favorably in the light twin jet helicopter market. It has been developed in the standard commercial configuration as well as

experimental military and naval variants for evaluation by the Italian Armed Forces. It is suitable in the civil field for most of the desired functions, including executive transport, off-shore operations, and ambulance operations. Total sales of all A-109 models are reported to approach 300, an impressive figure considering that the first year of significant market penetration was 1978, following its introduction into service in 1977 [12:77].

Agusta used the A-109 dynamic components to develop the A-129 Mongoose, the first European helicopter designed specifically as an anti-tank helicopter. First deliveries for the Italian Army are scheduled for 1986 and the program is reportedly on schedule [8:77].

Agusta estimates a worldwide requirement for about 1,000 light attack helicopters and is establishing a strong marketing effort to ensure a viable market share. As with other light attack helicopters, the emphasis is on heavy armament and battle survivability [8:102].

Agusta has established two marketing organizations in the U.S., the Agusta Aviation Corporation in Philadelphia (commercial sales and product support), and the Italian Aircraft Corporation of Arlington, Virginia (military helicopters). Agusta claims a twenty-four hour parts and service availability in the U.S. and its latest commercial offering, the 109 Mk II (one of the fastest light commercial helicopters

available) is targeted specifically at the corporate executive and emergency medical service markets.

Agusta has manufactured over 4000 helicopters, and, according to the Italian Aircraft Corporation, Agusta 1983 helicopter sales totalled 94 units at a value of \$530 million [12:77]. Agusta is now 80 percent owned by the Italian government, with the remaining 20 percent being owned by the Count Corrada Agusta, who serves as chairman of the board.

D. SOVIET COMPETITIONS

Soviet helicopter technology had its roots in the decade before the outbreak of the Second World War when the first flightworthy Soviet helicopter was developed. Four Soviet designers had a significant and lasting influence: Bratutchin, Yakovlev, Kamov and Mil.

J.P. Bratutchin entered the Central Institute, ZAGI, and from 1933 to 1939 headed the "helicopter brigade". In 1940 he took over the so-called OKB-3 (Test Design Bureau No. 3) which developed a range of helicopter types, some of which were produced in small numbers. This design bureau ceased to exist in 1952, having designed and built the Omega series of helicopters and their derivatives, the G-3 and G-4. These aircraft never entered production, but a small number of prototypes reached the flying stage. These led to the design of the B-5, B-9, B-10 and the only design to reach

flight test stage, the B-11. Problems of excessive vibration could not be cured, and after a fatal crash in 1948, the program was cancelled in May 1950 and the Bratutchin OKB was disbanded the following year [7:149].

A. S. Yakovlev started the construction of his first experimental helicopter in 1944, featuring a co-axial rotor system, a concept later adopted by Kamov. While test flying was in progress in 1947, the first state request for tenders for a light helicopter was issued, leading to the first flight of the Yak-100 in November 1948 and recognition by the State Acceptance Commission of suitability for series production in the summer of 1950 [17:1310]. The Yak-100 was copied from the Sikorsky S-51, however, the Mi-1, of the Mil design bureau was competing with Yakovlev and, because of its superior performance, was selected for production over the Yak-100. In 1951, Yakovlev was tasked to develop a heavy transport helicopter, intended to gain a lead over Anglo-U.S. helicopter construction. This program was only partially successful, with the tandem rotor design experiencing technical problems and being terminated after the production of only 40 units [17:1311].

N. J. Kamov started work on helicopters in the 1920s. Before and during the Second World War, Kamov headed the "design brigade" in ZAGI. In 1945, he started to build the Ka-8 light helicopter, based on the Yak co-axial design. This work led him to form his own design bureau. His first

production aircraft was the Ka-15, developed for the Soviet Navy as a light, two place utility helicopter which entered service in 1955. It was mass produced in large numbers for the Navy, and for civil applications as the Ka-15M. This success led to the Ka-18, larger and more powerful than the Ka-15, that commenced series production in 1956. This in turn led to the turbine powered Ka-20, a prototype for the Ka-25 ASW and missile targeting helicopter that has been the mainstay of the Soviet Navy's ship based helicopter fleet since the 1960s [17:1311, 8:114].

Closely linked to the success of Soviet helicopters is N. L. Mil who headed an independent design bureau from 1947 onwards. His first helicopter, the Mi-1 won the light helicopter competition against the Yak-100. The Mi-1 success led to the larger commando transport Mi-4, which after some initial technical problems entered service in 1953 and was produced in very large numbers (exceeding 5000). It has been used by both the military and the civil markets. Apart from specialized equipment, the military and civil versions are identical. They have been exported to almost every country that has received military assistance from the Soviet Union and to the Warsaw Pact nations [8:125].

In 1957, the Mi-6 was the largest operational helicopter in the world. Some 800 were subsequently completed for civil and military use, the civil versions being used in fire fighting, flying crane, passenger and general lift cargo

operations. These aircraft led to a stream of successful aircraft, including the Mi-8 (the most numerous Soviet helicopter, that entered service in 1967 and seeing vast service worldwide), the Mi-10 (60,000 lbs. heavy lift helicopter), the Mi-14 (shore based ASW derivative of the Mi-8 and introduced in 1975), the Mi-24 (the first true assault helicopter to be developed by the Soviet Union, and designed to be offensive in a hostile air/land battle environment and introduced in 1972), and the Mi-26 (at maximum gross weight of 123,000 lbs., the world's largest heavy lift helicopter).

Since the early 1950s, the helicopter has been widely used by both the military and civil sectors as a means of transport in Russia, particularly in those regions having long periods of adverse weather where the helicopter is often the only functioning means of transport. As a result, the number of helicopters operated by Aeroflot is almost as large as the military inventory, with the helicopters of the two fleets having almost the same configuration. The large production runs make for economies of scale and unit costs are about one-fourth those of comparable western helicopters. This advantage is offset by the Soviet practice of returning equipment for complete renovation after three overhauls, leading to high operating costs [17:1314].

In addition, the Soviets are proving to be difficult competitors, especially in the heavy helicopter field,

through their ability to grant financing terms that their western counterparts cannot match [18:344].

E. OTHER U.S. COMPETITORS

1. Kaman Corporation

The Kaman Corporation was founded as Kaman Aircraft in 1945. Over the years Kaman has developed into a widely diversified company. Kaman has a broad expertise in rotary wing technology and is currently producing the SH-2F ASW helicopter for the U.S. Navy. Kaman also produces composite rotor blades for the U.S. Army's AH-1 Cobra and major sub-assemblies for the Sikorsky civil S-76 helicopter. Kaman is potentially a significant force as a sub-contractor in the current JVX and LHX military helicopter programs.

2. Robinson Helicopter Inc.

The Robinson Helicopter Company was formed in 1973 to produce light civil helicopters. Current production is restricted to one model, the R-22, an ultra light, low cost, two place helicopter that has established a strong position as the prime civil trainer helicopter.

3. The Enstrom Helicopter Corporation

The R. J. Enstrom Helicopter Corporation was formed in 1959 to develop a light helicopter, leading to the Enstrom F-28 (first produced in 1966 and achieving a production run of 537 through 1983). In 1968, the company was acquired by the Purex Corporation. The Purex shares were acquired by

F. Lee Bailey in 1971. These shares were purchased by Bravo Investments BV of the Netherlands, the current owner of Enstrom, in 1980. Current production is the F-28, and the F-280 light civil helicopters [14:42].

4. Hiller Aviation, Inc.

Hiller Aviation was formed in January, 1973 by acquiring the design rights, production tooling, and spares of the Hiller 12E light piston engined helicopter from Fairchild Industries. Initially, the company provided support for the Hiller UH-12 (commercial designation Hiller 360) which had been produced in numbers amounting to 2,530 units up to 1983. In 1980, Hiller purchased all rights in the production of the FH-1100 turbine light helicopter from Fairchild Industries and delivered their first model in late 1981 [14:42].

In January, 1984, Hiller filed for protection under Chapter 11 of the Federal bankruptcy regulations, having failed to achieve satisfactory sales in the generally declining civil market [19:26].

Subsequently, the assets of Hiller Aviation were purchased by the Rogerson Corporation of California, with activities continuing under the name of Hiller Helicopters, as a Rogerson subsidiary, with deliveries of the UH-12 expected to commence in July, 1984, and the FH-1100 in January, 1985 (at production rates of one and a half, and one per month, respectively). [2:6]

5. Hynes Helicopter Inc.

Brantly Helicopters began commercial deliveries of its B-2 helicopters in 1959. From 1966 to 1968, Brantly was an independent division of Lear Jet Industries. The firm's type certificates, tooling and parts were bought by Michael K. Hynes in May 1971. This new corporation, the Brantly-Hynes Corporation, was involved in the reconditioning of Brantly helicopters, spare parts manufacture, operation of a flight school and the resale and servicing of used helicopters.

Hynes now has available the H-2 and H-5 series (two, three and five place turbo-piston, and jet-engine five-place twin-jet models in the light weight range).

F. SOME COMPETITORS WHO DID NOT SURVIVE

1. Competitive Situation in 1945

When the war ended in August, 1945, the U.S. helicopter industry consisted of four major competitors. Sikorsky had already produced 580 R4, R5 and R6 helicopters. Bell was just completing its third prototype, the Model 30 (the first prototype of the Bell Model 47). Piasecki was flying the PV-3, the tandem rotor forerunner of the U.S. Navy HRP-1 "flying banana". Hiller had developed the first co-axial helicopter in the United States, the XH-44. Several other firms, including Platt-LePlage, Kellet, Bendix, Firestone and GCA were developing prototypes. Sikorsky, Bell, Piasecki, Hiller, and later, Kaman survived. The other firms either disappeared or stopped their helicopter activities [7:154].

2. Platt-LePage

The Army Air Corps, after their contract with Platt-LePage for the XR-1 in 1940, wanted a larger machine in 1944. Platt-LePage proposed a twin engined machine, twice as big as the XR-1 but lost the contract to Kellet's XR-10. McDonnell absorbed Platt-LePage in the latter part of 1945 and developed the Platt-LePage losing design as the XHJD-1 for the Navy as an experimental ASW helicopter. The aircraft had significant control and stability problems. Flights with the XHJD-1 continued until 1950, including some hoist rescue tests in November, 1949 by the Arctic Rescue Helicopter Evaluation Board. The McDonnell Company eventually proposed the Model 65C, but were unable to win a contract and the project was abandoned [7:155].

3. Bendix

Bendix was created in 1944 and built an aircraft with two co-axial rotors, the K model, which flew in June, 1945, as an experimental model. They subsequently developed and flew the larger five place co-axial J model in 1947. In anticipation of rapid development and commercialization, Bendix built a 10,000 square meter factory in Stratford,, Connecticut, for production of 200 units per month. In 1947, Bendix ran into serious financial problems and the Model J prototype was destroyed in a crash. The company changed hands in 1948, becoming Helicopter Inc. Later, the firm was acquired by Gyrodyne Co. of America [7:156].

4. Gyrodyne Company of America (GCA)

GCA was created in 1946 and bought the five place Model J from Helicopters Inc. They also built a number of experimental compound helicopters, but finally developed the XRON-1, a single seat "aerial motorbike" for the U.S. Navy. The program was not commercially successful and the company's only significant production was the QH-50 unmanned Drone Antisubmarine Helicopter (DASH) for the U.S. Navy.

5. Kellett

Kellett produced their first helicopter, the XR-8 in 1944. They then produced the XR-10, the first U.S. effort at developing a twin engined helicopter in 1947. Failure to win significant military contracts, untimely deaths, and financial difficulties led Kellett to give up its helicopter activities in 1951. Part of the solution to Kellett's financial problems was the sale of the Kellett XH-17 (a military heavy lift requirement) project, to Howard Hughes in 1949. The aircraft became the Hughes XH-17, and though unsuccessful in its own right, it allowed Hughes Helicopters to enter the industry. Hughes Helicopters is now one of the four major U.S. manufacturers [7:156].

6. Firestone

The Firestone Company built the XR-9 for the U.S. Army in 1945. Developed as a battlefield liaison helicopter, it led to a civil version, the XR-9B, which was never certified.

This was followed by the Model XR-14, a larger twin seat helicopter which flew in 1946. Firestone was unable to win any military production contracts and stopped doing business in June, 1948 [7:157].

7. Doman

Doman Helicopter Inc. was formed on August 31, 1945. After early efforts with the LZ-1A and the LZ-4, the Doman LZ-5 (an eight place utility helicopter) was evaluated by the U.S. Army as the YH-31 in 1953. The military version was unsuccessful and the company had limited success with its commercial LZ-5, with a production run of 60. Doman then proposed the LA-5 in Europe and despite evaluation by the Marcel Dassault Company in France in 1956-57, was again unable to win contracts. Doman Inc. ceased doing business in 1961 [7:186].

8. Seibel-Cessna

Charles Seibel started his own company in 1946 after leaving Bell Aircraft. He developed several small helicopters, intended for the U.S. Army, but was unable to win military contracts or civil business and in 1951, he became the General Manager of the Helicopter department created by Cessna. There he designed the Cessna CH-1 Seneca, which obtained civil certification in 1951. Despite breaking several altitude records, the Seneca was never put into production. [7:189]

9. Rotorcraft Co.

The Rotorcraft Company obtained a U.S. Army contract to develop a tandem twin seat helicopter called the XR-11. The aircraft flew in 1948 but crashed in October that year. The project was abandoned and the company went out of business [7:190].

10. Other U.S. Companies

Other U.S. companies that attempted unsuccessfully to enter the helicopter business included the Hoppi-Copter Inc. (created in 1945), De Lackner Helicopter Company (created in 1945), the American Helicopter Company (created in 1947), Jenson (created in 1948), the Helicopter Engineering Research Corporation (created in 1948), Benson (created in 1953), and Convertawings Inc. (created in 1954).

All these companies were unable to convert their designs to successful production. The most significant contribution to their failure was their inability to win military contracts.

V. DEVELOPMENT OF THE HELICOPTER ENGINE

A. INTRODUCTION

In the 1480s, Leonardo da Vinci's efforts to achieve flight with his clockwork-powered helix failed, partly due to lack of power. In the early 1800s Sir George Cayley failed to generate enough power to fly his helicopter design. Many other early attempts at vertical flight shared this common drawback, i.e., lack of a suitable source of propulsion.

In 1903, the Wright brothers dramatically proved that man could, with adequate power, fly in a heavier-than-air vehicle. Five years later, in 1908, Louis Breguet, from France, achieved vertical flight in a powered helicopter.

Sikorsky's first attempts in Russia in 1909 also failed. His attempt flew, but without a pilot. Again, the limiting factor was the lack of power. In 1921, the de Bothezat helicopter, powered by a 180 hp LeRhône engine became what many consider to be the first successful helicopter, but the Army cancelled what was its first attempt to develop a military helicopter.

Vertical flight in the 1920s and the 1930s was marked by the successful development of the autogiro. These free wheeling rotor aircraft used conventional piston aircraft engines (up to 160 hp) for forward power. Not requiring power for vertical lift, these simple aircraft did not suffer the same power restrictions as the genuine helicopter.

B. PISTON ENGINES

All the early successful helicopter pioneers, Louis Breguet of France, Igor Sikorsky of the United States, Henrich Focke and Anton Flettner of Germany, recognized that, with the arrival of more powerful piston engines, rotary winged aircraft could become practical for military and civil use. They each used a common source of power, the air-cooled reciprocating engine, this being considerably lighter than the water-cooled engine. Air cooled engines were mechanically less complex and also less vulnerable to ground fire (when used in the military role).

In Europe in the 1930s, a number of designs successfully incorporated larger piston engines into helicopters, but the power-to-weight ratio continued to delay the progress towards a helicopter capable of being put into full production. This was not to occur until Igor Sikorsky successfully installed a 75 hp engine in his VS-300 prototype in 1939. Whilst this aircraft was underpowered, it was sufficiently successful to convince the U.S. Army to fund further development, leading to the more powerful XR-4. Wartime requirements and advancing technology led to the relatively rapid development of even more powerful and successful piston engines that were installed in the Sikorsky XR-4 in 1943, the Sikorsky S-55 in 1945, the Bell 47G in 1949, and the Piasecki H-21 in 1952.

Although piston engine power increased by a factor of seven between the mid 1930s and the early 1950s, the designers of helicopters continued to be aware that the practical development of rotary wing craft was essentially constrained by engine size, weight, and total power output [1:119].

The advent of the Korean War saw the introduction of the helicopter into real military service, demonstrating only too well the applications of the helicopter to tactical and logistic roles. But the power plant problem continued to plague the designers. The quest for more power resulted in heavier engines which required more space, which in turn required a heavier airframe, which led to a further requirement for extra power. As the power levels increased so did the level of airframe vibration, a highly undesirable side effect for helicopters. Helicopters were still, at that time, unable to carry anything other than a very small payload.

C. FIRST GENERATION TURBINE ENGINES

The end of this frustration was in sight in the mid 1950s, however, and helicopters entered a new generation following the successful results of propulsion development derived from more than thirty years of experience with piston engine turbo-superchargers. The gas turbine engine produced by this development was proved in fixed wing aircraft during and after World War II, offering the additive advantages of increased power and reduced weight. The helicopter engine

designer faced the challenge of harnessing this engine power, the result being the gas turbine turboshaft, with a shaft geared from the turbine rotor to the helicopter rotor. This event was reported, in 1955, to be a "spur to the helicopter" [21:1]. This Wall Street Journal article recognized that the new engine could reduce helicopter operating costs (at that time a significant factor restraining helicopter commercialization), add to helicopter safety (through the ability to use twin lightweight engines), and significantly increase helicopter performance capability.

In addition, gas turbines ran more efficiently at high power, (the normal operating environment of the helicopter), and were more reliable, having less moving parts. The net result was the ability to achieve both a significant increase in helicopter payload, and a better, more reliable, more fuel efficient engine.

In the early 1950s, U.S. gas turbines were installed in the Kaman-225 (which made the first gas-turbine-powered helicopter flight in history) and the Kaman HTK-1, a Synchropter. The French, however, made history with the world's first turbine powered helicopter to be produced in quantity, the SNCASE 3130 Alouette II, which flew in March 1955, powered by the 400 hp Turbomeca Artouste II engine, and which continued in production for twenty years.

In the U.S., General Electric, the Allison Division of General Motors, Lycoming, and Pratt and Whitney (Canada)

became the dominant producers of gas turbines for helicopters, whilst in Europe, Bristol-Siddely, Rolls-Royce, and Fiat were heavily involved. The gas turbine led to the highly successful second generation of military and civil helicopters.

The Bell UH-1 Huey was the first significant U.S. turbine success, being powered by the Lycoming T-53 engine that eventually had a production run of more than 17,000 units. In 1960, Lycoming was successful in powering the Boeing-Vertol CH-47 Chinook helicopter with the 2,200 shp T-55 engine.

Allison achieved success with its 250 hp T-63 turbo-shaft engine, first developed in 1958, and subsequently installed in a wide range of light observation helicopters and small civil helicopters.

Pratt and Whitney of Canada developed the PT6 family of small gas turbines in 1964, ranging from 1,020 shp to 1,875 shp. Its unique PT6-T Twin Pac (a twin engine single drive unit) is widely used in many applications. [1:123]

General Electric (G.E.), after considerable experience in direct power derived from gas turbines for land based applications, responded to a 1952 U.S. Air Force request for proposals for the development of a 600 hp helicopter gas turbine engine. The contract was awarded to Lycoming, but G.E. work on the program led to the evolution of a family of engines.

A Navy contract award to G.E. for the development of an 800 shp turbo-shaft engine led to the successful T-58 (weighing only 250 lbs. but producing 1,050 shp), with a dramatic 4.2 to 1 power-to-weight ratio, compared to the early piston engines that weighed more than their power output [1:125]. The T-58 was successfully tested in 1955 and first flew in a Sikorsky S-58 in February 1957.

Sikorsky also recognized the potential for gas turbine powered helicopters and designed the highly successful HSS-1 (commercial variant, S-61) around the T-58. The T-58 has subsequently been continually modified to meet a variety of applications. Power output increased from 1050 shp to 1870 shp, whilst weight went from 250 lbs. to only 443 lbs. and the specific fuel consumption (fuel used as a ratio of power output) was reduced by 20 percent. The T-58's commercial derivative, the CT-58, was the first U.S. gas turbine to achieve civil certification in July 1959.

D. SECOND GENERATION TURBINE ENGINES

In the late 1950s, and sponsored by the U.S. Navy, G.E. commenced a development program that led to the T-64, which powers the Sikorsky CH-53 family of heavy lift helicopters, as well as Short Take Off and Landing (STOL) aircraft and conventional fixed wing aircraft. Newer models of the T-64 produced 4,855 shp but, through advancing technology, the specific fuel consumption and weight figures have both been reduced.

E. THIRD GENERATION TURBINE ENGINES

During the Vietnam experience, the U.S. Army saw a need for a new generation of helicopters and engines, and, in 1967, funded a competitive program for the development of a new, lightweight, fuel efficient, low maintenance turbo-shaft engine. The competition was won by G. E. in 1972, leading to the development of the T-700 which powers the Sikorsky UH-60A Black Hawk, SH-60B Seahawk, and HH-60H Night Hawk; the Hughes AH-64 Apache; the Bell AH-1T Cobra; and several international aircraft [1:127]. G. E. was awarded a production contract for 1554 T-700 engines in 1983. This government funded research and development led in turn to the development of a civil derivative, the CT-7, which has been certified in both the U.S. and Europe. The CT-7 was selected to power the Bell 214 ST and the Westland 30-200 civil helicopters in the early 1980s.

The rapid development of the gas turbine engine has, to a great extent, driven the evolution of the helicopter industry. The engine milestones have permitted the helicopter to transition from one generation to the next and the continued technological improvement against the commonly accepted measurement criteria of fuel efficiency, maintainability and reliability, and weight has permitted an ever increasing spectrum of civil and military uses and capabilities. For example, helicopters can now be used in a wide range of temperature and altitude conditions, from freezing cold icing

conditions to hot and high mountainous conditions; operating costs are decreasing, making transportation and public service more viable; and speed has increased, spurring one of the emerging markets, the air ambulance.

As in the case of airframe technology, the government has played a key role in advancing engine technology, through its funding of military development programs.

F. CURRENT ENGINE PROGRAMS

The involvement of the government is being continued with research and development programs sponsored jointly by the National Aeronautics and Space Administration (NASA) and the U.S. Army's Aviation Systems Command (AVSCOM). These are the advanced compound turbine diesel engines, the 5000 shp modern technology demonstrator engine (MTDE), destined for the Bell/Boeing Joint Services Vertical Lift (JVX) program, and the 800-1, 200 shp Advanced Technology Demonstrator Engine (ATDE) destined for the Army's proposed LHX family of light helicopters.

The Army narrowed the MTDE development competition to the General Electric G. E. 27 and the Pratt and Whitney PW3005 turbo-shaft engines in 1983. Development is expected to be completed in mid 1987, with full scale engineering development of the winning design to be completed in 1990. The first flight of the JVX, scheduled for mid 1987 will be with an interim power plant, the G. E. T64 [20:117].

The Army's increased emphasis in the development of the LHX family of helicopters elevated the importance of the ATDE program. Two configurations, the AVCO Lycoming PLT34A and the Detroit Diesel Allison GMA500 turbo-shaft engines were tested in the development phase, completed in 1981.

The ultimate performance requirements of the ATDE engines will have to wait until the Army decides on the required speed range of the LHX, according to the deputy chairman of the LHX trade-off determination board, but:

the engine must be able to adapt to different vehicle configurations that include conventional helicopter, rigid rotor and tilt-rotor designs. Top speeds from 180-300 knots are still under consideration at this time for the LHX. [21:123]

Engineering development for a production ATDE engine is scheduled to begin early in Fiscal Year 1985. The Army's intention is to compete 40 percent of the LHX program, and following a competitive teaming arrangement for development, to qualify two sources, commencing with the first production buy. [22:64]

With the Army forecasts indicating a requirement for at least 5,000 LHX vehicles, the program ensures long term production of the winning engine design, with opportunity for the development of very cost competitive turbo-shaft and turbo-prop versions for the commercial market [20:123].

Whilst not formally reported, it appears that the two teams for development may be Allison/Garrett and PW Canada/

Lycoming. A possible foreign entrant may include a version of the Turbomeca TM333, marketed in the U.S. by the General Electric Company. [20:123]

While the Western World's market for high power engines is basically shared between four companies, there are eight manufacturers competing in the medium power turbo-prop/turbo-shaft field (i.e., 500-2,500 shp). Supplier/customer relations have tended to become established along national lines, with Turbomeca supplying Aerospatiale, Rolls Royce supplying Westland and U.S. manufacturers in general relying on the American engine makers. Allison's Model 250 has dominated the light end 400-500 shp market, due in large part to large orders from the U.S. military which allowed the company to break into the civil market with hard to beat prices [23:1000].

This segment of the engine industry has some complications. Unlike the big engine industry, they do not share that industry's economies of scale. The price that can be charged for an engine is largely a function of its size, but this relationship does not hold for new engine development. This requires a substantial re-investment of sales to research and development (higher than the industry norm) and makes the contribution of military development funding crucial. [23:1000]

In Europe, advanced European helicopter turbo-shaft equipment programs are focused on developing more powerful, lighter

engines. Many of these new engines are being developed under multinational programs to meet the political and industrial requirements of their parent joint helicopter programs, thus allowing producers to share the technical tasks and financial costs.

These programs involve arrangements between Turbomeca and Rolls Royce, Turbomeca and Motoren and Turbinen Union (MTU), and Turbomeca as a sole developer. Work is focused, as in the U.S., on improving engine fuel efficiency, increasing the use of electronic engine controls, decreasing the number of engine components and upgrading maintainability [23:125]. In the United Kingdom, Rolls Royce is also running four demonstrator engine programs to provide the technology needed for helicopter developments in the late 1980s and 1990s. Two of these are with Turbomeca, and the other two funded by the British Department of Trade and Industry [20:125].

The early pioneers, da Vinci, Cayley, Breguet and de Bothezat all experienced the limiting factor of power, which prevented them from lifting a helicopter off the ground with a profitable payload. The gas turbine removed that constraint and the turbo-shaft helicopter now performs useful work at a reasonable cost [1:131].

VI. TECHNOLOGY DEVELOPMENT

A. INTRODUCTION

Little more than 40 years after Sikorsky and Focke Achgelis first made helicopters that worked, the machine is beginning to attain a level of technological development in which it can respond to customers' specific requirements. Up until recently, the military customer has taken the best the manufacturer could provide, and the civil operator has made do with civilianized versions of the military helicopters. Hence the Sikorsky S-61, the Boeing-Vertol 234, the Bell 205, the Bell Jet Ranger and Long Ranger, and the Hughes 500E, to name but a few. Four notable exceptions are the Agusta 109, the Aerospatiale Ecureuil, the Sikorsky S-76, and the Bell 222, all specifically designed for civil markets. But the helicopter is still a weakling by the standards of the fixed wing industry, struggling to reach a comparable level of dependability and simplicity of operation. [24:523]

This chapter will address some of the main differences between the European and American approaches to helicopter technological development. Much of the material has been drawn from a report prepared under the auspices of the AIAA by representatives of the four major U.S. helicopter manufacturers. [Ref. 14]

B. COMMERCIAL VS MILITARY DEVELOPMENT CYCLES

The development of a new helicopter model is both expensive and time-consuming. New models are generally introduced about every 15 years. Between models, companies generally improve existing models through incremental modifications to discrete parts of the helicopter. These may be manifested either as new "derivative" models, or as upgrade kits to existing models. In this way, high start-up costs are recouped, and companies are better placed to respond to a quickly changing market.

When a new helicopter is designed, the first step is the development of the design specification, followed by engineering development, where the design is prepared for quantity production. For civilian helicopters, company test plan, and flight programs are approved by the Federal Aviation Administration (FAA). The FAA must also certify the helicopter before any civil sales can be made [14:19].

Military helicopters are more expensive to develop than civil helicopters and require a much longer development cycle. Contributing factors are the greater sophistication of military requirements, the more rigorous nature of military specifications, the requirement for more stringent test and evaluation, and the inevitable time penalty of the government competitive selection, approval, and funding process. These factors can cause a military program to

stretch out to 8 to 10 years, whereas a comparable civil development program may only take 4 to 5 years. [14:20]

As previously stated, most helicopter development in the U.S. has had military origins, and it is widely apparent in the published literature that the U.S. helicopter industry considers itself disadvantaged with respect to the European industry because of this fact.

C. U.S. VS EUROPEAN DEVELOPMENT APPROACHES

Any helicopter manufacturer must remain abreast of technology advances in order to retain or improve market share. The technology intensive nature of the industry demands the expenditure of large sums of money to advance the state-of-the-art. History has shown that, in general, major technological advances have been brought about by military funding and that these technologies have been incorporated into commercial models at a later date. Most of the successful commercial helicopters have their roots in a military funded program. In the seventies, largely as a result of the expanding civil market, particularly in the commercial oil exploration segments, U.S. manufacturers, for the first time, developed specific commercial designs (the Bell 222 and the Sikorsky S-76). Whilst these development programs used company funds, they incorporated technology that had been developed and funded in previous military programs. [14:21]

Military and civil programs have a fundamental difference relating to program and business risk and it is this difference that makes incremental improvement built on military funded technology a necessity for commercial programs. For commercial programs, a company is faced with beginning an expensive development program, with an uncertain and fickle market projection extending 20 years into the future. As a result, industry funded commercial programs are driven to shorter development lead times and the use of concurrent rather than advanced technology [14:21].

The AIAA report on the U.S. helicopter industry stated that:

....the objective of government-funded programs is to advance the state-of-the-art, while the objective of commercial programs is to reduce these advances into economical practice and achieve rapid introduction to the commercial market place. [14:21]

The European helicopter industry is fundamentally different from the U.S. industry. Each European company is a heavily subsidized sole source supplier to its own government, heavily dependent on exports for survival, and particularly heavily dependent on civil exports. The U.S. dependence on exports has not been so heavily pronounced, with the preponderance of U.S. military orders, but the civil market and the export market is becoming increasingly important. A key difference is that in the United States, there are four major manufacturers who must compete for all requirements.

Whilst this protracted military competition is occurring in the United States, the technology is also available to overseas manufacturers through the relatively liberal dissemination of research results by the National Aeronautics and Space Administration (NASA). The European dependence on civil exports, combined with government objectives of full employment and industrial development, has led to a much greater awareness of the need to develop helicopters with the civil market in mind and results in the American developed technology being fielded in European civil helicopters before it is able to be fielded in U.S. civil helicopters. This technology transfer also permits the European companies to concentrate their Research and Development (R and D) efforts on specific and fruitful areas of key technology, such as composite structures. [14:21]

Whilst the European manufacturers are recognizing civil requirements in their initial designs and designing specifically for the civil market (e.g., the Aerospatiale Ecureuil, the Agusta A-109, and the MBB-Bo-105), a reverse trend is occurring in the United States. In the past, military technology was relatively easily transferred into commercial models. In recent years, however, military requirements have become so specialized that the designs are not incorporating the qualities required for commercial success. Military requirements are stressing survivability, low life-cycle cost, stealth, and maneuverability, leading to highly

specialized and expensive helicopters such as the Sikorsky UH-60A Black Hawk and the Hughes AH-64 Apache. In contrast, the commercial buyer is demanding reliability, safety, comfort, low acquisition costs, and productivity [14:22]. These factors are making it increasingly difficult for U.S. manufacturers, who are optimizing their designs to win U.S. military competitions, to compete against the civil oriented designs of the foreign competitors.

D. FUNDING OF HELICOPTER DEVELOPMENT

U.S. helicopter development requires a substantial investment of R and D funds. In terms of direct funding, the military development programs are the major recipient, with very little, if any, direct funding provided to commercial programs. A company can benefit in one of two ways. The government can provide direct funding support in the form of direct dollars for rotorcraft technology development contracts. The bulk of these funds are provided for U.S. Army and Navy development programs (such as the Navy/Marine Corps JVX program and the Army LHX program). Each of these sources has provided more funds for rotorcraft R and D than has the NASA budget over the six-year period from 1978. It is apparent from Table 2 that the U.S. Army has been the primary sponsor of military funding for rotorcraft technology development over this period.

TABLE 2

U.S. ARMY/NAVY RDT & E - HELICOPTERS

(MILLIONS OF DOLLARS)

	FY78	FY79	FY80	FY81	FY82	FY83
<u>CURRENT DOLLARS</u>						
ARMY	308.1	293.3	291.6	298.1	290.2	327.7
NAVY	4.0	113.0	224.0	154.0	95.0	50.0
<u>CONSTANT DOLLARS (1)</u>						
ARMY	205.0	179.4	163.9	152.6	138.8	149.3
NAVY	2.7	69.1	125.9	78.8	45.4	22.8

(1) Fiscal Year GNP Deflator

A company may elect to conduct Independent Research and Development (IR and D). U.S. manufacturers can recoup some of their R and D investment in commercial programs if the technology has military potential. The government may allocate a certain percentage of the company's self-initiated and self-funded IR and D to products and services sold to the government in the year of incurring those costs, the amount of allocation being a negotiated percentage of the firm's approved IR and D program. Significantly, if the firm has no ongoing program with the DoD in that year, no IR and D cost allocation is possible. This latter factor makes it important for a company to have defense contracts in order

to recoup such expenses. From 1974 to 1980, the portion of IR and D allocated to all DoD contracts fell from 40 percent to 30 percent, whilst the figure has increased to 38 percent in 1982. In general, this means that for each IR and D dollar charged to defense contracts (in 1982), \$2.65 of contractor IR and D was performed, i.e., defense contractors must invest in R and D out of profits or commercial sales to maintain their technological position. [14:22]

Both American and European governments fund Research and Technology (R and T) by providing funds to research activities. A comparison of U.S. and European funding is provided in Table 3, revealing that the total level of funding is similar.

TABLE 3

CIVIL AERONAUTICS RESEARCH FUNDING THROUGH PUBLIC
RESEARCH INSTITUTIONS-EUROPEAN NATIONS AND
UNITED STATES

1980

(MILLIONS OF DOLLARS)

BELGIUM	6.1
FRANCE	92.3
GERMANY	83.3
ITALY	6.9
NETHERLANDS	N/A
UNITED KINGDOM	<u>89.2</u>
SUBTOTAL	278.3
UNITED STATES	308.0

The major recipient of such funding is NASA. Even though NASA's individual budget is larger, the European R and D contribution is comparable. Observing that any technology transfer has historically (with few exceptions) been one way from the U.S. to Europe, the European community has benefited from U.S. funded R and D and so their total available R and support may well exceed the U.S.-funded R and D. The transfer of substantial R and D technology (through licensing, co-production, and offset agreements) permits the European research community to focus on commercially beneficial research areas such as fuel efficiency and maintenance reduction, giving the European manufacturers a further advantage in civil helicopter development.

NASA's R and T budget since 1978 is shown in Table 4. In real terms, aeronautics R and T funding increased between 1978 and 1980, decreased in 1981 and 1982, and improved again in the 1983 and 1984 estimates. In percentage terms, the NASA rotorcraft R and T funding increased from 7 percent of the total agency aeronautical funding in FY 1978 to 17 percent in the proposed FY 1984 budget. The FY 1984 budget is double the FY 1978 budget in real terms, primarily as a result of the emphasis on advanced technology projects, such as the X-wing, the tilt-rotor, and the Rotor Systems Research Aircraft programs. [14:23]

TABLE 4

NASA RESEARCH AND DEVELOPMENT BUDGET AUTHORITY
AND THE AERONAUTICAL COMPONENT

(MILLIONS OF DOLLARS)

	FY78	FY79	FY80	FY81	FY82	FY83 (1)	FY84 (1)
<u>CURRENT</u> <u>DOLLARS</u>							
TOTAL NASA R&D	3102	3477	4088	4336	4738	5543	5709
AERONAUTICS R&T	228	264	308	271	265	280	300
ROTORCRAFT R&T	17	21	32	31	42	45	51
<u>CONSTANT</u> <u>DOLLARS</u>							
TOTAL NASA R&D	2064	2127	2298	2220	2266	2525	2469
AERONAUTICS R&T	152	161	173	139	127	128	130
ROTORCRAFT R&T	11	13	18	16	20	20	22

(1) Estimate

(2) Fiscal Year GNP Deflator

E. TECHNOLOGY TRANSFER ISSUES

A prevailing theme through much of the literature has been the view that the U.S. helicopter industry is threatened by the liberal approach of the U.S. Government to the question of technology transfer. As shown earlier in this thesis, every major European helicopter manufacturer was connected in some way (either by licensing agreements, co-production, or off-set agreements) with the U.S. helicopter industry. There is no question that the European industry was able to take advantage of the U.S. preoccupation with its commitment to the Vietnam conflict and to use licensed American technology to work its way down the learning curve. Allegations have been made by American manufacturers, associations, and writers close to the helicopter industry that the European manufacturers enjoy an unfair advantage in the market place. The alleged advantages include the view that U.S. industry and the U.S. Government are too open with respect to sharing technical data of a non-sensitive military nature with other countries and companies, leading to a reduction of R and D costs and development periods. [12:72]

Technology dissemination has always been encouraged by the United States through professional societies and forums. The U.S. helicopter industry, however, has expressed concern over the "much more intimate dissemination" taking place as a result of government-to-government Memoranda of Understanding (MOUs). These MOUs are intended to eliminate NATO system

development effort duplication (with its consequent resource wastage). The MOUs provide for government-to-government technology exchange agreements in order to share the common military technology base. The U.S. industry claim is that while these MOUs originated to facilitate the exchange of information in highly specialized technical areas, they have in reality, often been vaguely defined and broadly interpreted. Since the data concerned is applicable in general, to both military and commercial applications, the technology transferred via MOUs is transferred to the European civil helicopter technology base (since European helicopter development centers are contained largely within nationalized companies). This technology transfer process, it is claimed, has permitted the Europeans to concentrate research efforts in key areas (where good returns are indicated) whilst relying on U.S. technology to provide broad-based technology advances. The U.S. industry is concerned more with basic research than with developed technology since it is the basic research of today that provides the competitive advantage of tomorrow [14:25].

U.S. manufacturers have found that, if they are to sell helicopters overseas, they must be prepared to commit to licensing, co-production, or co-operative efforts. By this method, many overseas countries are demanding the transfer of technology in order to develop organic manufacturing capabilities and helicopter technology. In this way manufacturing is gradually diffusing away from the high-technology

countries and the traditional aerospace manufacturing companies. [24:526]

As previously stated, the European industry has achieved success partly as a result of many bilateral MOUs and technology transfer agreements between the U.S. and Europe. A more recent development has been the growth of technology transfer within Europe, as evidenced by the ever-increasing number of intra-European collaborative development projects (e.g., Westland-Agusta, Aerospatiale-Westland, and Aerospatiale-MBB). These arrangements have stimulated a number of exchange programs having a similar organizational structure and purpose as the American MOUs, but include not only government agencies, but also manufacturers and universities, and are truly multilateral. [26:39]

The net result of these factors is a general feeling throughout the industry that the U.S. helicopter industry is coming under increasing pressure from overseas competition, not only in the overseas markets, but perhaps more ominously, on its home ground, the domestic U.S. market. The statistics provided in Chapter III would appear to support this view.

VII. MILITARY REQUIREMENTS

A. INTRODUCTION

From a reading of the earlier chapters, it will be apparent that the U.S. military requirements played a significant role in the development of the helicopter industry, particularly in its formative stages. The Korean War and the Vietnam War provided a military demand that resulted in the concept of such confrontation being drastically altered. There have been many military procurements in this first forty years. This chapter will briefly describe those procurements that are judged to have had a pronounced effect on the industry, in that they either enhanced or degraded the competitive position of the contenders.

B. THE EARLY REQUIREMENTS

The early requirements of the military have already been well addressed in Chapter II. Sikorsky was the first to take advantage of military requirements when he successfully produced the R-4, R-5, and R-6 helicopters that were evaluated in many roles. This contract award established Sikorsky as the early world leader in helicopter production.

Bell was able to respond to the Army Air Corps requirements for an observation helicopter brought about by the Korean conflict in the late 1940s, after making several

hundred Bell Model 47s for a civil market that did not eventuate. Through fortuitous good timing, Bell was able to satisfy the Army requirement for in excess of 300 helicopters at short notice. The only viable competitor, Sikorsky, was not production ready with the advanced S-52 (a development of the earlier R-6) and could not deliver. This win established Bell as the leader in the light helicopter business and led to a long line of civil derivatives.

Piasecki also entered the business by building a demonstrator, the PV-2, followed by the tandem rotor PV-3 (the tandem rotor design enabled greater lift with the available engines and avoided center-of-gravity problems that troubled the early Sikorsky designs).

Following the end of World War II Sikorsky had developed the R-5 to the S-51 as a private-venture and won military contracts with Navy, Air Force, and later the Coast Guard. The S-51 was significant for Sikorsky in that it saw the beginning of licensed overseas production and the beginning of commercial scheduled airline use. [1:33]

At the same time, Piasecki had convinced the Navy to contract for the 10 place HRP-1 and the 14 place HRP-2 helicopters, both developments of the tandem rotor PV-3.

Thus by the late 1940s Piasecki, Sikorsky and Bell had used private funding to develop helicopter models sufficiently successfully to win the first exploratory military contracts.

C. THE S-51 REPLACEMENT COMPETITION

Sikorsky had improved its early R-5A helicopter with private funds to the S-51, which was subsequently procured by the U.S. Navy and Coast Guard as the H03S and the Air Force as the H-5D. It was used in the rescue role. In 1946, the Navy conducted a design competition to replace this helicopter, looking for more lift and performance and a five to six place helicopter. The Piasecki XHJP-1 tandem rotor helicopter (developed from the privately funded PV-3, HRP-1) was selected. The configuration, overlapping and inter-meshing rotors, was unconventional and untried and the Navy ordered a back-up program. This was the Sikorsky XHJS-1, which was a development of the Sikorsky S-51. The resulting fly-off led to production of the Piasecki contender as the HUP-1, owing to center-of-gravity problems that troubled the Sikorsky helicopter. During this time, the Air Force had cancelled its last five Sikorsky H-5 rescue helicopters and modified the associated contract in order to obtain funding to build the H-19 (Sikorsky S-55) to meet a requirement for a larger, higher-performance helicopter. This approach enabled the Air Force to acquire an advanced state-of-the-art helicopter without the long wait associated with funding approval and formal competition requirements for new procurements.

It also enabled Sikorsky to apply funding to resolve its earlier center-of-gravity problems of the S-51. The S-55/H-19

was now acceptable to the services and the Navy and Air Force ordered the helicopter as the H04S and the H-19, with deliveries beginning in 1950 [1:33]. This sequence of events favored Sikorsky as the HUP lagged behind in delivering and orders from the Air Force and Navy were increased. The S-55 became the first ASW helicopter to operate from aboard ship and achieved early use in scheduled airline service. A total of 1067 S-55s was built for military customers by Sikorsky, in addition to 547 built under foreign license [8:290]. Notwithstanding the HUP production difficulties, it was still produced in substantial numbers, being popular with Navy for the Vertrep function (since the tandem rotor design made them relatively insensitive to wind direction). The production run of 321 enabled Piasecki to survive this period.

D. AIR FORCE RESCUE HELICOPTER COMPETITION - 1950

In 1950, the Air Force conducted a competition for an air-rescue helicopter. Again, Piasecki won the competition, this time with the H-21 Workhorse, which was another, larger development of the HRP-1 that had spawned the HUP. The H-21 was a 12 to 20 place tandem helicopter designed as a rescue helicopter for the Navy and as a troop transport/medical evacuation helicopter for the Army and Air Force. The production run eventually amounted to 727 helicopters, as the H-21 was to become the Army's Vietnam workhorse.

However, in a pattern that was becoming familiar, the Air Force again issued a contract modification to the Sikorsky H-19 production contract, reducing the quantity by five to fund a back-up for the Piasecki H-21. This action funded Sikorsky to produce the H-34 (S-58), a 13,000 lb. twenty place helicopter. The H-21 program experienced production problems and delays, leading to increased military orders to Sikorsky for H-34A (Army), HSS-1 (Navy) for ASW, and the HUS-1 (Marines) [1:37]. Again this opportunity was significant for Sikorsky, as the S-58 commercial production was 329 units, and military deliveries of the H-34 amounted to almost 2000 units [8:296]. It saw wide civil service after being certified in 1956 and was produced widely overseas by license.

Thus, whilst this phase of competitions was going on, Piasecki had twice won the competition but, owing to production lags and some technical difficulties, Sikorsky was able to play catch-up and won the greater share of production, although Piasecki's experience was sufficient to keep his design approach competitive.

E. MARINE CORPS ASSAULT REQUIREMENT - 1951

The Navy conducted a design competition for a large assault helicopter for the Marine Corps in 1951. Sikorsky was chosen to build the Sikorsky S-56 (Navy HR2S, Army H-37) [1:39]. Piasecki at this time was committed to an Air Force

contract for a large, general purpose transport and rescue helicopter, the YH-16, which was ultimately cancelled, owing to technical difficulties). The S-56 was not dramatically successful but provided an opportunity for Sikorsky to develop heavy lift technology. A total of 154 were eventually produced but the helicopter was the progenitor of a line that was to lead to the Sikorsky success in the heavy lift and heavy assault helicopter roles.

F. THE NAVY INTERIM ASW REQUIREMENT

In April 1950, the Navy decided to procure ten H-19s (being developed for Air Force evaluation) equipped with dipping sonar for evaluation and initial ASW capability. This helicopter was designed the H04S-1. Engine problems resulted in some Piasecki HRP-1 helicopters being diverted for evaluation. The Navy preferred the tandem rotor design because of its superior hovering efficiency and greater center-of-gravity range. The Piasecki HUP (developed from the HRP-1) was therefore developed as the interim ASW helicopter. The HUP also ran into engine difficulties, allowing Sikorsky to re-enter the competition with a re-engined H04S-1, which was subsequently developed as the interim ASW helicopter. The HUPs' engine problems were resolved by engine derating, eliminating any prospect for the ASW mission due to payload requirements. At this stage Sikorsky had only to withstand one more challenge before dominating the ASW helicopter market [27:72].

G. THE NAVY ASW MISSION REQUIREMENT

While the interim development was proceeding, the Navy held an industry wide competition for a new helicopter specially designed for ASW. In June 1950, the development contract was awarded to Bell for the HSL. Bell chose to adopt the preferred tandem rotor configuration, but chose a single engine configuration, instead of the two engine layout desired by Navy. At 18,000 lbs., the HSL was the largest free world helicopter of the time.

Sikorsky again benefited from military lack of confidence in risky programs. The Navy ordered the HSS-1, similar in layout to the H043/H-19 as insurance. It was specially designed for shipborne use, with a folding tail boom and folding main rotor blades. The HSL, as feared, experienced technical problems whilst the smaller Sikorsky helicopter proved equal to the specified ASW task and was more shipboard compatible. The HSL program was cut back to 50 and the HSS-1 became the Navy's standard ASW helicopter. It operated as a hunter rather than a killer, since the carriage of torpedoes restricted the fuel load [27:73].

H. THE ARMY UTILITY HELICOPTER REQUIREMENT

The turbine engine raised the helicopter's already high price tag by a large margin, this being the main reason why the civilian turbine helicopter market was slow to take off. But its efficiency and relative ease of maintenance made large

scale military usage a reality. Although over 2000 helicopters were purchased by the military during the Korean conflict, most military men considered that the helicopter would be useful for little else than an aerial ambulance. When the Army sought industry proposals for its first turbine powered helicopter in 1954, its main requirement was a cabin large enough to carry three litter patients and a medic.

Bell Helicopter won the contract in 1955 with the turbine engined UH-1 Iroquois (the "Huey"). This was a new class of helicopter, larger than the two seat observation helicopters (the Bell 47 and the Hiller 360) but smaller and cheaper than a full scale transport. The product positioning was both shrewd and responsive to the Army requirements. Bell delivered the first Iroquois in 1959 and slowly introduced improvements that satisfied the Army and blocked any competitors. The absence of any military contracts (which could help to underwrite development costs) prevented other competitors from building similar models. [28:124]

The Huey production run (inclusive of military and civil variants) amounted to more than 10,000 units, remaining in production until 1981. This win reinforced the position of Bell in the light/intermediate transport/utility helicopter market and provided access to a valuable potential civil market, as well as developing a basis for derivative development into the interim attack helicopter requirement that was to eventuate as a result of the Vietnam conflict.

I. THE ARMY HELICOPTER TRANSPORT REQUIREMENT

In 1958, the Army decided to replace its Sikorsky and Vertol piston powered transports with a larger and faster turbine helicopter. The Boeing Model 107 was developed in the late 1950s for evaluation by the Army as a medium lift transport. Ten were ordered by the Army in 1958 as the YHC-1A but this order was cut back to three when Vertol produced its Model 114 the next year. Five Model 114s were purchased as the YHC-1B and were considerably larger than the 107 [8:193]. Vertol won the Army contract in 1959 with the huge, 51-foot long CH-47 Chinook (developed from the Model 114). Potential sales were promising enough to convince Boeing to purchase Vertol in 1960. At the outset, the Chinook was designed as an aerial truck, its size and shape being dictated by the Army requirement to carry the Pershing I missile system. [28:124]

At this time, the Army attitude to helicopters was changing and the Marine Corps had totally revised its tactics to take advantage of the mobility and speed of helicopter units. In late 1959, the Army decided to standardize on two helicopters already on order (the Bell Huey and the Boeing Chinook) and a new observation helicopter.

Whilst the Army (and to a lesser extent, the Air Force) settled on the Chinook, the Navy and the Marine Corps chose the Model 107/H-46 as their light transport/medium assault helicopter. At this time, with Boeing's production capacity

being stretched to the limit, the Navy/Marine Corps requirement for a heavy assault helicopter was satisfied by the Sikorsky initiative to internally fund the Sikorsky S-60, which in turn derived from the military contract for the Sikorsky S-56 Marine Corps assault helicopter in 1951. The CH-53A was in fact a hybrid helicopter, employing the dynamic components of the S-64 Flying Crane and an enlarged version of the S-61/H-3 Sea King fuselage [8:309]. Yet again, Sikorsky was able to take advantage of the DoD's cautious approach to the ability of Boeing-Vertol to produce on schedule. This contract win for Sikorsky led ultimately, in the early 1980s, to a further contract for the free world's largest helicopter (the Sikorsky S-65A/H-53E Super Stallion). The Sikorsky CH-53 series was chosen as the basis for the Navy/Marine Corps requirement for a heavy lift helicopter capable of lifting 16 tons in 1973, as the original S-65 design had a provision for the addition of a third engine [8:314]. The S-65A was chosen over the Army proposed Boeing-Vertol Heavy Lift Helicopter (HLH) design.

J. THE ARMY LIGHT OBSERVATION HELICOPTER REQUIREMENT

This was one of the most interesting and significant military competitions. An industry-wide competition to build the Army's new Light Observation Helicopter (LOH) started in the winter of 1959/60. It was a critical contract, for the potential order was about 4000 units. It was also

apparent to the makers that a modified version of the high speed, maintainable aircraft would have a good civil market. The three main bidders were Bell, Hiller, and Hughes. Bell already had the successful Bell 47 in the Army inventory and were confident of success. Hiller had built all the remaining Army LOHs (the Hiller 360/H-23 Raven) and also appeared to have a good chance. However, the prospects were so good that 44 companies submitted 119 design concepts (including conventional light planes and other types of vertical take-off aircraft). Hughes had previously developed the 269A light piston two place helicopter with company funds, but did not immediately win any military contracts. In May of 1961, the competition was narrowed to Hiller and Bell. However, Hughes was invited back into the competition (the basis for that decision not being clear) and each company was contracted to build five prototypes around a new Allison turbine engine. The Government funding was \$6 million for each company but \$2 million of private funding per company was required to complete the delivery of the prototypes.

In 1964, the Army eliminated the Bell contender, as a result of testing, and announced that a decision between Hiller and Hughes would be made on price. All three helicopters (the Bell OH-4, the Hiller OH-5, and the Hughes OH-6) were remarkable helicopters but it appeared that Bell may have suffered from complacency.

In its request for design, the Army had indicated that it would not increase the helicopter performance or capability by later design modification. Hiller apparently decided that every other military helicopter had been successively improved whilst in production and designed a sturdy helicopter that could accept a later performance improvement without major airframe changes.

Hughes, on the other hand, offered the Army what it wanted, a stripped down optimum design, lighter by 400 lbs. and much faster than the Hiller bid. The Hiller helicopter was sturdier and more reliable but the Hughes helicopter was a much better performer. The choice was made on price, with both makers bidding to take a loss on the first production run of 714 helicopters. Hiller's cost was reported to be about \$35,000 and their bid was \$29,000. Hughes, who wanted to get into the business, underbid Hiller with a bid of \$19,680. This "buy-in" bid was successful. [28:124]

Shortly after the LOH competition was finalized, Hughes consolidated its position by winning another contract away from Hiller for a \$5.5 million order for 215 primary helicopter trainers. This sequence of events spelt doom for Hiller, who lacked the corporate strength to commercialize its unsuccessful LOH contender. Bell, with substantial financial reserves, was faced with the potential loss of its traditional light helicopter market. To prevent this, the

OH-4 dynamic components were used to develop the highly successful Bell 206 Jet Ranger, which sold 3729 units through April, 1984.

This competition gave Hughes the start it needed. After winning, Hughes reportedly stated that, after the initial order, the price would be based on cost plus reasonable profit [28:124]. After Congressional interest in this competition, the subsequent re-procurement in 1968 was re-opened to competition and Bell and Hughes both bid (Hughes with its production LOH helicopter and Bell with its Bell 206 Jet Ranger as the OH-58A). On this occasion, Bell was successful and the Army has since procured over 2200 units. Hughes had been able to enter the industry, however, and, through the military funding, had achieved success with the OH-6. They, in turn, commercialized the OH-6 as the very popular Hughes 500 that has sold 3651 units through 1983, in many different variants.

This win was important to Bell in that it gave them good access to a later contract, the Army Helicopter Improvement Program (AHIP) that selected the OH-58D over the Hughes OH-6.

K. THE ARMY ATTACK HELICOPTER REQUIREMENT

The story of the attack helicopter is a saga in itself. In the beginning, when helicopters began to be shot at in combat, aviators developed improvised defensive measures. This started with hand held weapons but evolution brought

weapons systems that the pilot could fire by aiming the helicopter. The French began this development in Algeria in the 1950s.

Once a defensive capability had been validated, it was a quick logical extension to ground force support, troop helicopter escort, and for independent attack missions. Initially, available helicopters were used (e.g., the UH-1 Huey), but these rapidly evolved to the narrow bodied streamlined fuselage that is now typical [1:133].

United States attack helicopter development pursued two objectives. The first, escort and soft target suppression (as in Southeast-Asian jungle warfare), was satisfied by quickly modifying existing helicopters into suitable attack helicopters. The second, the capability to combat heavy armoured tanks (for which Europe is the most likely theatre) was addressed by the development of purposely designed helicopters, such as the Lockheed AH-56 Cheyenne and the Hughes AH-64 Apache [1:133].

1. The Early Attack Helicopters

The Bell Sioux Scout was built by Bell to demonstrate the firm's concepts in attack/gunship helicopters. This helicopter incorporated a number of features found in subsequent armed attack helicopters and was used as a test bed for several advanced devices (e.g., a "hands-off" tracking gun sight that could be directed by movement of the pilot's head). Developed from the Bell Model 47, it set many standards

for future armed helicopter design. It first flew in 1963 but did not itself gain production status, serving primarily as a company-funded conceptual demonstrator. [8:178]

Meanwhile, in 1962, the Army's Tactical Mobility Requirements Board (the Howze Board) officially endorsed, for the first time, the use of armed helicopters in the escort role. The Vietnam War demonstrated the validity of this concept, and armed Bell UH-1 Hueys were pressed into the gunship role. This was an emergency measure only, and the Army issued a requirement for an attack helicopter in 1964. Alternatives examined included the Boeing-Vertol CH-47, the Sikorsky S-61, the Kaman UH-2, and the Bell D-262 (a radical new design). Initially, Bell was eliminated from the competition on the basis of technical risk. [8:179]

The Kaman UH-2 gunship option had earlier been considered for the escort role, and Congressional approval for a procurement of 220 UH-2s had been given in 1963. The program was dropped in favor of the Bell UH-1 Hueys from Texas, five days after the assassination of President Kennedy and the succession of Lyndon B. Johnson to the Presidency. [1:98]

After being eliminated, Bell continued to develop their attack helicopter concept as a private-venture under the Bell designation, the Model 209. The Bell 209 was resubmitted to the Army in August, 1965, when it became obvious that the Vietnam War did, in fact, require a radical new concept. The development start gained by Bell was invaluable

and the Army were sufficiently impressed that they ordered an initial buy of 100 209 Cobra gunships in April, 1966. Series production followed, and Bell continued with their well proven philosophy of offering continual product improvements to keep the customer happy and to block competition. Such improvements included twin engined configurations for reliability (for marine applications), a rotor brake, and improved armour and armament, including the fitting of the Tube-launched, Optically-tracked, Wire-guided (TOW) missile system.

Sikorsky did attempt to dislodge the Cobra with the Sikorsky S-67, which was a high speed helicopter gunship developed as a private-venture in response to the Vietnam combat experience. It was derived in part from the S-66 (Sikorsky's paper entrant in the AAFSS contest; see next section) and used the dynamic components of the S-61 Sea King. Sikorsky obtained several Government contracts to evaluate specific S-67 features, but customers were not attracted, as the Huey Cobra was proving quite adequate for the immediate task. [8:316]

2. The Purpose-Designed Attack Helicopter

The 1962 Howze Board report recommended that an attack helicopter be developed to provide close-in support and anti-tank capabilities. This led, in 1964, to an Army Request For Proposal (RFP) for an Advanced Aerial Fire Support System (AAFSS). Besides seeking out and destroying

enemy tanks, it was expected to provide escort for the Army Boeing-Vertol Chinooks, while making quick sorties from the line of flight, and to clear landing zones. To do this, the aircraft required performance characteristics on the remote edge of the state-of-the-art, particularly with respect to high dash speed, hover capability, and ferry range.

[1:138]

The AAFSS contract quickly came down to a choice between Sikorsky and Lockheed, who both submitted designs for winged helicopters using a conventional rotor for lift and a tail propeller for high speed forward flight. Lockheed offered the AH-56 Cheyenne and Sikorsky the S-66 for the paper competition. Lockheed appeared to have the performance edge necessary to satisfy the demanding requirements of the Army and was contracted for ten development prototypes.

Lockheed had entered the helicopter field only a few years before, with a radical concept involving the combination of a hingeless rotor and a rotor-mounted control gyro, which gave excellent results on two small helicopter designs. It was this radical concept that attracted the Army selection board [1:139]. Unfortunately, the concept did not transfer readily to the larger prototype Cheyenne and the program ran into serious technical difficulties. Simultaneously, the Army changed the concept of the combat helicopter. The Vietnam experience indicated that high speed was not essential, but that survivability was, leading to a twin

engine requirement. These two factors destroyed the Cheyenne program, and with it, any hopes Lockheed had of entering the helicopter business. The Cheyenne program was cancelled in August, 1972, and a new competition for the Advanced Attack Helicopter (AAH) was commenced in November, 1972. Although Lockheed submitted a proposal for the AAH, it was too late to play catch up. Development contracts went to the Hughes AH-64 Apache and the Bell AH-63 [1:139], following bids from Bell, Boeing-Vertol, Hughes, Lockheed, and Sikorsky.

Bell had earlier been eliminated from the Utility Tactical Transport Aircraft System (UTTAS) design competition in the early 1970s (see next section). During interviews, Bell indicated that they may have lost that competition following a rather casual and complacent approach to the proposal, in much the same way that they had lost the earlier initial LOH contract. Their approach to the AAH competition was apparently an overkill reaction to that loss, with the result that their contender, the AH-63 was heavier and did not perform as well as the Hughes AH-64 Apache. A significant difference was the approach to development and production. Bell relied on their own manufacturing capacity whereas Hughes teamed with firms of proven expertise in various fields, with Hughes acting as responsible integrator of systems and assembler. This enabled Hughes to bring the best technology together, to build a better, faster, higher performing helicopter than Bell, and to quote a cheaper

price. Bell also insisted on providing a two bladed rotor design. This design had served the company well throughout the years, but Bell failed to recognize that, in spite of the relative technical merits of the two bladed versus four bladed systems, the customer had a preference for the four bladed system [1:140].

After fly-offs, the contract was awarded to Hughes in December, 1976. The Apache program offers a long production run for Hughes and was sufficiently attractive to prompt McDonnell Douglas to acquire Hughes in January, 1984, in a move that makes Hughes a formidable competitor in future competitions.

L. THE ARMY UTILITY HELICOPTER REPLACEMENT

Bell, Boeing-Vertol, Hughes, and Sikorsky all submitted paper designs for the Army RFP for the replacement of the Bell UH-1 utility helicopter. The Bell and Hughes proposals were eliminated and contracts awarded in August, 1972 to Boeing-Vertol and Sikorsky to design, build, and test three prototypes. Both entries shared many characteristics, an indication of the increasing emphasis the DoD was placing on driving the specifications to meet military requirements.

This competition was critical for Sikorsky. The loss of the AAFSS contract to Lockheed had left Sikorsky with only bits and pieces of the military market, mostly the production of the CH-53As for the Marine Corps. In 1966,

Sikorsky's president estimated that his plant was at 40 percent capacity [28:124]. Thus, success in this UTTAS competition was essential for the survival of Sikorsky. Their approach was to take a meticulous and rigorous approach to the Army requirement, together with a continuous dialogue with the Army on the specifics of the requirement. Their product, the S-70 (UH-60) was very close to the specification.

Boeing-Vertol did not have the experience of Sikorsky in this helicopter configuration (the single main rotor that Sikorsky had pioneered) and was not able to play "catch up", despite using an innovative rotor design adapted from the MBB Bo-105 (Boeing-Vertol had obtained the American license for the MBB Bo-105 in order to rapidly gain small helicopter innovative technology and experience). [8:200]

The contract was awarded to Sikorsky on 23 December, 1976 and the UH-60 Black Hawk has given Sikorsky wide access to a range of further contracts (e.g., the Navy ASW helicopter contract, won by the Sikorsky SH-60B against a Boeing-Vertol re-entry of its losing UTTAS contender and a modification of the Westland/Aerospatiale Lynx).

M. SUMMARY

The preceding list of procurements is by no means exhaustive but it does provide an indication of how and where the major competitors won and lost. Bell's position was established by the Bell 47 and Huey successes and later

by the initiative of the private-venture Cobra. Sikorsky and Piasecki fought out the heavy helicopter segment, with Sikorsky probably emerging with the greater share of the spoils. However, Piasecki (later Boeing-Vertol) was able to win enough contracts to survive. Kaman was moderately successful but never succeeded in competing on equal terms with the big four U.S. makers and restricted its efforts initially to crash/rescue helicopters before achieving moderate success with destroyer based ASW helicopters for the Navy.

Hughes entered the market with an aggressive pricing strategy and was able to drive Hiller out of the military business, grab light helicopter market share from Bell (in the LOH program) and seize the initiative in the anti-tank attack helicopter market.

The common thread in all the competitions was the absolute necessity for a company to bid on military requirements in its chosen segments. On occasions, this tactic required corporate strength to fund the private development of product offerings. Design also had to be such that, even if the military competition were lost, the design could be commercially adaptable (e.g., the Hughes OH-6 leading to the Hughes 500 and the Bell OH-4 leading to the Jet Ranger).

VIII. MANUFACTURER/GOVERNMENT RELATIONS AND MARKETING ISSUES

A. INTRODUCTION

A prevalent view held throughout the U.S. helicopter industry is that the U.S. manufacturers are at a disadvantage when compared to their European competitors as a result of the differing European government approach to industry development. This chapter will explore the nature of the U.S. industry view, as reflected in a recent report on the U.S. helicopter industry [Ref. 14], and will specifically address the comparative nature of the manufacturer/government relationships, government support of product marketing, foreign military sales, and financing issues. It will also briefly examine the impact of early licensing agreements provided to European firms by the leading U.S. firms and a more recent phenomenon, the overseas collaborative helicopter development agreements (often occurring at a government-to-government level).

B. MANUFACTURER/GOVERNMENT RELATIONS

In the United States, the DoD is the major purchaser of privately produced helicopters. In contrast, the European governments either own or control their helicopter industries. There are, therefore, some differences in the

manufacturer/government relationships that dictate the way the helicopter business is conducted.

In Europe, where nations seek to pursue independent foreign policies, reliance on imported military equipment is seen as a potential constraint to that nation's freedom of action. Foreign policy issues (e.g., that nation's influence over less developed countries) are critical in developing an industry that becomes increasingly dependent on exports for survival. For example, in France, over 85 percent of the helicopters produced are exported. Thus, a successful industry can be a major factor in assisting the achievement of a favorable balance of payments. Aerospace, being a high technology industry, is also a definite stimulus to the development of associated technologies, with further benefit accruing to the overall technology base of the country concerned. [14:27]

Accordingly, in the government owned or controlled companies of Europe, factors that contribute to the criticality of the aerospace industry are taken directly into consideration. These factors include the support of foreign policy initiatives, the contribution to the balance of trade, advancement of the national technology base, enhancement of national prestige and increased employment opportunities for the labor force. Thus, when such a company approaches new business, bid and pricing decisions are based on a

"national accounting system", rather than the much narrower "profit accounting system" of a pure commercial enterprise, and embrace the spectrum of national socio-economic and foreign policy issues that can and are set against the purely business concepts of monetary profit. [14:28]

By contrast, the aeronautical industry in the United States has developed primarily within the private sector. Product line and business decisions are based on two objectives, firstly, the need to offer products that are sufficiently competitive with regards to price and performance to win competitions, and secondly, to bid a price that will cover costs and reasonable commercial profit. The second objective may sometimes require a conscious decision to either not bid in a competition, to bid low (and take a loss) or to bid with the objective of using government funding to achieve R and D applicable to other lines of business. In other words, the U.S. market is characterized by fierce competition in both the military and civil sections [14:27]. This competitive environment dictates that U.S. companies must be able to sustain sometimes lengthy attacks on their market share by other competitors. History has shown that only those firms with substantial financial reserves have been able to survive. All the major U.S. firms are now parts of much larger corporate empires. Those firms without large corporate financial reserves have fallen

by the way (e.g., Hiller, who was all but eliminated by Hughes in the LOH competition in the mid 1960s).

New helicopter introduction is a lengthy process and requires a substantial investment in development. The return on investment is extremely difficult to predict, particularly in the civil sector, being dependent on market forecasts that stretch fifteen to twenty years into the future. Helicopter related R and D is funded from a number of sources; equity, debt, retained earnings, government funds provided under contract, and from operating income. These sources are used by both American and European firms in differing proportions [14:28]. U.S. helicopter manufacturers raise much of their funds in the equity and debt markets, where the perceived degree of business risk dictates the rate of return required by the investor. This rate will always be higher than the yield rate on risk-free U.S. Government Treasury Bills and could be as high as 20 - 30 percent on a risky helicopter program. R and D is perceived as a particularly high risk investment, with the possible returns being derived many years after the investment, leading to a very high cost of capital for R and D financing. This factor again makes it important for the modern U.S. helicopter manufacturer to achieve military funding for R and D efforts. In the absence of military funding, the company has to justify to the parent corporation that the combination of risks and returns for the project in question is superior

to that which can be achieved elsewhere in the diversified product line of the corporation [14:28]. With the helicopter business being so technology intensive, continual R and D investment, regardless of source, is necessary in order to remain in a sufficiently competitive position to be able to bid on RFPs.

The AIAA maintains that this is significant cost disadvantage for American industry, claiming that the cost of government furnished funds to the European companies is essentially zero, leading to a gradual erosion of U.S. technological leadership, particularly in an era of high interest rates. In support of this view, the AIAA states that there are several ways that foreign governments contribute to the funding of their state controlled firms. Acting as a stockholder, the government can and does provide infusions of equity funds (e.g., such funding was provided to Aerospatiale in the period 1970 to 1978 when Aerospatiale was suffering a continuing series of losses; \$70 million was provided in 1970, \$14 million in 1973, \$108 million in 1974 and \$124 million in 1976). [14:29]

Government owned or controlled firms may have difficulties in attracting equity financing, being perceived as less profitable than private firms. However, because of the implication of government protection against default, the firms can carry a higher debt-to-equity ratio, and at a

less punitive interest rate, leading to a reduction in their cost of capital. [14:29]

An alternative form of subsidy available to the European firm is the government loan or loan guarantee which allocates to the government a share of future revenues generated from the program being funded. These loans may be repayable only if the program is commercially successful, with the AIAA maintaining that payments are not required until break-even point is reached, with the French industry being a major recipient of this type of funding. The Puma helicopter, developed by Aerospatiale, was funded in a program where the government participated to the extent of 50 percent in the development program and shared in the subsequent revenue. Aerospatiale also has access to financial aid aimed at promoting exports and programs displaying economic or social value. [14:29]

The AIAA draws two further distinctions between European and U.S. practice in relation to financing practices. First, the U.S. DoD is concerned solely with the development of helicopters to meet pure military requirements, there being no direct intent to develop products or technology for commercial application. This situation does not prevail in Europe, where developmental aid is provided for the funding of commercial programs (e.g., the British/Italian EH-101 and the MBB/Kawasaki (BK-117) intermediate sized utility helicopter). Second, U.S. military procurement policy is

concerned with meeting a threat to the national security and, as such, is often funded on a stop-go basis, as the perceived threat shifts. On the other hand, foreign governments, particularly the French, fund their programs as part of a long term industrial policy, with a twenty year planning horizon. The U.S. short term policy approach is, therefore, both a constraining factor to commercial helicopter development and a business risk exacerbating factor. [14:29]

The U.S. helicopter industry points to the existence of four competitive firms in the U.S., compared to Europe, where each major firm is the sole supplier in that country and deduces that this leads to a competitive disadvantage for the U.S. firms. This deduction stems mainly from the position of the U.S. Government as the sole buyer for the military helicopter output. Helicopter manufacturers must devote considerable effort and resources to the competition. Foreign military sales may permit recovery of some of those costs, but they do not constitute an acceptable substitute for the large production base of U.S. military orders [14:30]. These factors are compounded by the business risk of military helicopter program development time, often unpredictable, lengthy and subject to cyclical policy change. The longer the development time, the longer the manufacturer must wait before earning profits and before being able to commercialize the product. For eight U.S. military helicopters introduced

from 1960 to 1982, the average development period was nearly eight years. [14:30]

Civil helicopter program risks have much in common with military business risk already discussed. In addition, the civil craft must be designed to fit into long term market forecasts highly susceptible to the risk of unpredictable events. For example, the events that boosted civil helicopter applications were the rapid rise of petroleum price in the 1973/74 timeframe (leading to the requirement for more fuel efficient helicopters) and the oil embargo during the same period that spurred off shore oil exploration in remote areas (leading to a requirement for long range, high capacity helicopters). Because of the long development times required, the helicopter industry is now producing those purpose-designed helicopters (the commercial Chinook, the Bell 222 and the Sikorsky S-76) at a time when the civil market has slumped, and the helicopters are now being reconfigured as utility, corporate/executive and commercial vehicles in order to boost sales. [14:30]

C. GOVERNMENT SUPPORT OF PRODUCT MARKETING

All nations with organic helicopter industries have established government agencies to support the sales efforts of those countries' firms. In France, the Delegation Generale pour L'Armement (DGA) has overall responsibility for the production and sale of French weapons. The Direction des

Affaires Internationales, an office within DGA, is responsible for maintaining growth in French weapons exports, with arms deals being managed at the highest levels of government and supporting major foreign policy initiatives (e.g., half of the French arms exports in recent years have gone to the Middle East, upon which the French are so dependent for their future oil supply). [14:31]

In similar fashion, England has established the Defense Sales Office (DSO) within the U.S. Ministry of Defense to promote the export of arms. This organization not only assists British manufacturers in the sales of arms overseas, but advises the Defense Ministry of overseas requirements during the initial design of British products, so that they can be modified where appropriate, to enhance overseas sales prospects. [14:31]

The AIAA reports that, in contrast, the U.S. approach has been "vacillating and at times restrictive". Legislation introduced in 1976 was framed to reduce the number and size of military assistance groups in foreign countries and instructed government personnel to "refrain from any activities that would stimulate overseas requests for U.S. supplied arms". [14:31]

The legislation was expanded to curtail if not eliminate the promotion of arms sales by government officials and private firms. This same legislation also forbade U.S. firms

from making any significant modifications to U.S. arms in order to enhance overseas sales, restricted the initiation of co-production arrangements with foreign firms, and reaffirmed and strengthened the restrictions on sales to countries alleged to be consistently involved in human rights violations. As a result of this policy, according to the AIAA, "614 requests from 92 countries totalling more than \$1 billion were turned down in the first fifteen months of the Carter Administration". [147:31]

These issues have been softened somewhat by the Reagan Administration, but the earlier restrictions on overseas trade have, it is alleged by the AIAA, permitted the European firms to gain a foothold in many emerging overseas and third world markets. Further, the inconsistency in the United States' arms export policies is a possible deterrent to overseas arms sales which require a reasonable assurance of stability in both policy and deliveries. This is provided as a contributing reason for the rapid growth of French military exports, since France views such transactions as being purely commercial and "less dependent on the recipient nations meeting some ill-defined moral standard". The example of the speed with which France resumed arms shipments to Argentina after the Falklands dispute is given to support this view. [14:32]

D. FOREIGN MILITARY SALES

The helicopter has become an integral part of the battle-field strategy of almost every developed nation. The U.S., with its heavy emphasis on quick reaction and rapid deployment, has an especially critical need for helicopter production capability. Helicopter unit costs are greatly influenced by the length of the production run and the quantity ordered. The associated learning curve is quite steeply sloping, so as the production run is lengthened, the marginal unit production costs and average unit costs decrease. Overseas military sales can have a significant effect on the cost of domestic military sales, and thus the denial of foreign military markets, either through increased competition from overseas firms or through restrictive U.S. Government policy can be detrimental to the U.S. helicopter industry.

[14:33]

The existence of healthy military export markets also adds to the surge and mobilization capability of the industry, a vital aspect of national security readiness. The increasing tendency of the European nations to close their doors to American imports through European collaborative programs has potentially serious repercussions on both the costs of domestic helicopter production and the level of national security preparedness.

In further criticism of the U.S. Government involvement, the AIAA maintains that the involvement of the U.S. DoD in

Foreign Military Sales (FMS) tends to lengthen and complicate the already complex process with potential customers, enhancing the competitive position of the foreign producers. In a quoted example, a company (unnamed) that initiated a potential procurement and did much of the lead up work, eventually lost the sale to a competitor during the open competition required under the FMS program, although the marketing effort had been started as a direct sale. [14:34]

E. FINANCING

The U.S. helicopter industry, already troubled by falling sales as a result of the world economic recession, is also feeling the impact of foreign sales practices and incentives that are not able to be matched by domestic producers. In recent years, high interest rates have made sales financing a critical factor in closing sales. In general, available financing programs have not been as competitive as those of other nations. Whereas U.S. private lending institutions are reluctant to make loans on aviation products for foreign customers at competitive rates, foreign governments are often more than willing to make those loans, in line with their national goals of developing industrial capability, promoting domestic goods in world markets, and creating domestic employment. For those nations, entering into potentially high risk loan agreements is an acceptable expense when offset against the achievement of long term national policy objectives. [14:36]

For U.S. firms, the alternatives are to finance a short-term five to seven year loan through the firm's corporate structure, or to work through the Export-Import Bank (Eximbank). The former is usually as unacceptable as a private institution, with competitive interest rates being too low to be commensurate with the degree of risk. The Eximbank, however, has not been heavily involved in financing helicopter sales. Eximbank funds have generally been channelled to high value products which have made more substantial contributions to the U.S. balance of trade, and are more widely available to large commercial jet transport manufacturers. In 1981, the Eximbank reported to Congress that its medium-term credit support "did little good for U.S. exporters facing subsidized competition, except that it gave them a fixed base from which to reduce the rate further". [14:36]

Comparative figures for medium-term fixed export credit effective interest rates are provided in Table 5. [14:36] As can be seen, U.S. rates were generally well above those of European competitors, being roughly double those of England and France. However, the Eximbank, in late 1982, announced a new medium-term loan program for aircraft costing less than commercial jet transports. Under this program foreign purchases of helicopters may be financed with the aid of Eximbank loan guarantees to financial institutions, who in turn can arrange fixed rate financing with the foreign buyer. Such financing is limited by the bank's charter to commercial sales. [14:37]

TABLE 5

MEDIUM-TERM FIXED EXPORT CREDIT
EFFECTIVE INTEREST RATES

(PERCENT)

		1979	1981
FRANCE	(a)	8.00	8.75
GERMANY	(a)	8.30	10.05
JAPAN	(a)	7.85	9.85
UNITED KINGDOM	(a)	N/A	8.60
UNITED STATES	(b) (1)	11.33	17.05
	(2)	12.58	18.30

(a) Face rates adjusted up to effective rates by accounting for insurance, guarantee, and commitment fees in the following amounts: France (0.75), Germany (0.8), Japan (0.60), and United Kingdom (0.60).

(b) Line (1) represents effective rates assuming only a 0.25 percent discount loan commitment fee. Line (2) assumes a 0.25 percent discount loan commitment fee plus a 1.25 percent fee for optional insurance.

Many of the countries with which the U.S. competes have signed the General Agreement on Tariffs and Trade (GATT), which prohibits signatories from offering low-cost, below-market loans or other subsidies in order to make a sale. The impact of GATT has been weakened, since interest rates in other countries have generally been lower than in the United States. As a result of an export credits "war" centering on sales of commercial jet transports, the major

industrial nations, through the Organization for Economic Co-operation and Development (OECD), concluded a "standstill agreement" in 1976 on terms of aircraft export financing. This agreement defined a "commonline" (a minimum export financing rate and a maximum loan term), however, as interest rates fall in the U.S. the interest rate has become of less significance than the market "term". Currently, the "common-line" agreement does not cover general aviation or helicopters, and, without the inclusion of rotorcraft, the U.S. helicopter manufacturers will continue to compete at a disadvantage against the low-cost packages offered by foreign firms. The GATT agreement does not apply to transactions involving military helicopters and U.S. military helicopter manufacturers must compete against foreign manufacturers offering prices or financing (subsidized by state support) that feature very low initial downpayments and/or interest rates far below market. In terms of price, the U.S. manufacturers must set a price that includes a proportionate share of development costs in addition to production and administrative costs in order to show a profit. Foreign firms that are government owned and supported have much more flexibility in pricing, since they are not so constrained by the need to recover costs and make a profit. [14:37]

F. INTERNATIONAL LICENSING

It is widely recognized throughout the helicopter industry that the European industry achieved its technological start by virtue of production licensed from U.S. firms. Aircraft firms license their products for a number of reasons. In some cases, a licensed production agreement enables a firm to get into a market that would otherwise be unavailable to it; in other cases, licensing enables the developer to obtain added income from his design when he is already producing to capacity (e.g., when Bell licensed Dornier to build the UH-1D in Germany in 1965, Bell could not support any helicopter production beyond their commitment to the U.S. Army); in yet other cases, licensed production satisfies a political objective. [29:15]

The Sikorsky S-61 is the generic identifier for a family of large turbine powered helicopters, comprising nine civil and fourteen military versions. The S-61 evolved from a Navy contract issued in 1957 for an ASW helicopter. Production for the Navy began in 1959, and in April, 1960, Sikorsky issued the first S-61 license to Mitsubishi in Japan. It was then licensed to United Aircraft in Canada in 1963, and to Westland Aircraft in England and Agusta in Italy in 1966. By the end of 1973, over 200 S-61s had been produced by Sikorsky licensees, and by 1980, 371 had been built. Sikorsky's earlier licensing experience had included an agreement with Westland in 1947 for the production of the S-51

helicopter, agreements with Westland, Mitsubishi, and Aerospatiale for production of the S-55, and with Westland and Aerospatiale for production of the S-58. A total of 1217 helicopters were produced under these agreements. Through September, 1979, the total Sikorsky production was 5545 helicopters, whilst Sikorsky's overseas licensed production was 1672 helicopters. [29:31]

In December, 1969, Sikorsky entered an agreement with the government of the Federal Republic of Germany for licensed German production of the large CH-53D/G. Sikorsky had tried to sell the helicopters to Germany, but the Germans wanted a share of the production. Under the agreement, the final contract specified that at least 40 percent of the purchase price, including fees and royalty payments, would be spent in the U.S. [29:51]

Bell Helicopters sold a production license in 1952 to Agusta for production of the Model 47 piston engined helicopter, and to Kawasaki of Japan in 1953 for production of the same helicopter. In 1960, a license was issued to Agusta to build the Model 204B, followed by a further license to Agusta for the Model 205A in 1963. The second Model 205A license went to Dornier of Germany in 1965, the third to the government of the Republic of China in August, 1969, to be followed by a further license to Fuji as a follow-on to an earlier Model 204B license. [29:37]

The Boeing-Vertol Company had been in the helicopter business since shortly after World War II (under its earlier names of the Piasecki Helicopter Corporation, and the Vertol Aircraft Corporation). Vertol's first experience with licensing was in 1954 when they licensed the HUP and H-21 rotor blades to firms in the United States and France. In 1956, they licensed the H-21 in France, and in 1959, they licensed their first turbine powered helicopter, the CH-46, to Kawasaki in Japan. In March, 1968, Boeing-Vertol concluded an agreement which led to the production of the CH-47C in Italy by Agusta. Boeing-Vertol decided on this licensed program because they had not been able to penetrate the helicopter markets in Italy, the Near East, the Middle East, and the African countries, areas in which Agusta had been successful with license built helicopters for many years. [29:45]

It can be seen that, although each of the major European manufacturers is now producing its own designs to fill world wide markets, achievement of their present level of competitiveness would have been substantially delayed were it not for the early assistance, both in design and manufacturing technology, provided by the leading U.S. manufacturers with whom they now compete. [14:15]

G. CO-PRODUCTION

A different kind of business environment and development outlook is now emerging in the free world helicopter industry external to the U.S., and is reflected in the increasing number of collaborative arrangements between manufacturers in several countries in the development of new models. These arrangements enhance the partner's competitiveness by the merging of complementary strengths, the elimination of major home competition, and, through sharing, reduce the risk in product introduction. The AIAA concludes that it is not unlikely that the American helicopter manufacturers will face a multinational threat similar to that presented by Airbus Industries to the U.S. commercial jet transport industry. The AIAA also maintains that American firms are at a disadvantage in initiating or participating in such arrangements amongst themselves, owing to uncertainties with respect to the interpretation of anti-trust statutes.

[14:38]

The major teaming effort in Europe is the recently announced program that joins MBB and Aerospatiale in the development and production of one basic helicopter to satisfy the requirements of the French and German military. The PAH-2 attack helicopter is being arranged by government-to-government MOU and is receiving substantial government funding. The U.S. firms (especially Hughes, with the AH-64 Apache) attempted unsuccessfully to enter this program.

The second major teaming effort is that between Westland of England and Agusta of Italy, again with government funding support, to produce the EH-101 helicopter with both civil and military objectives. These types of international cooperation agreements will aid the European firms in reducing the risk in developing new aircraft. In particular, financial risks will be cut and the agreements give the European firms the chance to benefit from shared technology. [30:11]

John Zugschwert, Executive Director of the AHS, suggests that the U.S. Government may have to change its tactics as current U.S. firms are being excluded from profitable international cooperative programs. Besides the European teaming efforts already mentioned, MBB is teaming with Kawasaki of Japan and Hindustan of India (the BK-117 and a new advanced light helicopter respectively), and other subsidiaries and joint programs are being established in Japan, the Peoples Republic of China, Indonesia, India, Australia, Canada, and South America. [30:11]

IX. THE FUTURE OF HELICOPTERS

A. INTRODUCTION

The growth of all sectors of aviation in the last fifty years has been dramatic. The growth of the helicopter sector has lagged behind the fixed wing sector by about thirty-five years, mainly because of the initial difficulties in achieving stable vertical flight. Significant investment in R and D by both national industries and governments has brought the helicopter to the verge of the fourth generation of hardware. Reliance on design evolution by experimenting with modest incremental departures from proven designs also slowed the early development of the rotary wing sector. The indications are that the fourth generation will entail a quantum step forward in technology applications, ranging across the entire range of aerodynamic and electronic disciplines. This chapter will address the future of the helicopter industry by examining the activities of some of the agencies involved in helicopter technology and will comment on how these activities will provide a basis for creating a wider market for helicopter use. [1:221]

B. TECHNOLOGICAL CHALLENGES

The way ahead in the 1990s has been largely clarified by the R and D budget passed in the U.S. Congress in 1978,

from which stemmed the Rotorcraft Task Force created by NASA to assess the state of helicopter technology, determine needs, and develop a research program for the future development of advanced civil and military rotorcraft. In its Task Force Report on Advanced Rotorcraft Technology dated 15 October, 1978, [Ref. 31] NASA proposed a \$398 million U.S. dollar, ten-year research program, with eight goals; noise reduction, vibration reduction, reliability and maintainability improvements, safety improvements, flying qualities improvements, productivity improvements, and reduced fuel consumption. The Task Force identified four major program elements, aerodynamics and structures, propulsion, flight control and avionics systems, and vehicle configurations. R and D under these program elements involves NASA, DoD, and the FAA in a number of broad, technology developing programs. [10:155]

1. Aerodynamics and Structures

In the aerodynamics and structures element, the focus is on three areas: acoustics, vibration, and composites. The goal is to develop a method for future helicopter design that reduces external noise by 5 - 10 decibels, improves hover efficiency by 10 percent and improves cruise efficiency by 20 percent. An important program in this area is the U.S. Army Advanced Composite Airframe Program (ACAP) in which Bell Helicopter and Sikorsky Aircraft are building competitive demonstrators of composite technology (using

the Bell 222 and the Sikorsky S-76 designs). These should yield a 20 to 30 percent weight reduction, a 15 to 20 percent reduction in cost, with additional benefits in improved aerodynamic performance and dynamic response, and better field repairs and lower maintenance costs. [1:225]

2. Propulsion Systems

The propulsion systems elements' main objectives are to improve engine and power transfer technology, reliability and maintainability, reduce engine fuel consumption, and reduce power-plant manufacturing and operating costs. The propulsion technology programs now underway promise significant improvements that will be attained in production engines in about ten years. They include the 800 horsepower Advanced Technology Demonstrator Engine (ATDE) that will contribute to the LHX program and the 5000 horsepower Modern Technology Demonstrator Engine (MTDE) that may well find a home in many applications (e.g., the CH-47, the P-3 Orion and the JVX). Both these programs were the subject of competitive development contracts awarded by the U.S. Army. Two other engine concepts are notable. The first is the convertible engine that provides shaft power to rotors at hover and low speed and then converts to a turbo-fan mode for high speed cruising. The Defense Advanced Research Projects Agency (DARPA) and NASA are funding a Convertible Engine Systems Technology program that has possible applications in high speed rotorcraft concepts, such as the Advancing Blade

Concept (ABC) aircraft, the Folding Tilt Rotor aircraft and the X-wing aircraft (discussed later in this chapter). The second is the Compound-Cycle Turbine-Diesel Engine (CCTDE) that has many potential applications for future rotorcraft programs that will require 500 to 1500 horsepower [1:228].

High operating costs of current helicopters are largely due to the maintenance rate of the transmission components; therefore, much of the propulsion program is aimed at improving transmissions in order to achieve reductions in noise, weight and cost, while improving reliability and maintainability and achieving longer life. This combined effort should bring a 20 to 50 per cent increase in the mean time between removal. [10:156]

3. Flight Controls and Avionics

The flight controls and avionic systems element involves the applications of advanced technology and includes improvements in fuel efficiency, maneuverability, flying and ride qualities, precision flight-path control, and decreases in pilot workload. Additional benefits include reduction of vehicle weight by the substitution of fly-by-wire or fly-by-light control systems. The avionics thrust will mean that multiple, identical, self-healing digital electronic systems can be used, and mission adaptability and role versatility will improve dramatically. The pilots workload will be able to be reduced to the point where the single pilot cockpit will become a reality. Flight control systems will

be self-adaptive and mission reconfiguration will be achievable by module changing. One such program is the U.S. Army Advanced Digital/Optical Control System (ADOCS) Flight Demonstrator Program. Under this program, Boeing-Vertol is designing a new computerized helicopter flight control system that will be tested in a Sikorsky UH-60 Black Hawk and will have future application in the LHX program. [1:230]

Higher Harmonic Control (HHC) for vibration suppression has also been demonstrated in a funded program involving the U.S. Army, NASA, and Hughes Helicopters (with the Hughes OH-6A configured with HHC flying in 1983). The new control technologies and the electronic cockpit will allow the helicopter to be linked to advanced guidance and navigation systems, such as the Navigation system using Time and Ranging (NAVSTAR). This will allow much more effective use of airspace, particularly in congested terminal areas. The FAA's CH-53 research and development helicopter has demonstrated in-flight helicopter navigation using NAVSTAR, and NASA is exploring low-cost civil guidance systems that can use degraded signal inputs from military global positioning system satellites now being put into operation. [1:230]

4. Advanced Rotorcraft Configurations

The fourth and last major element of the program is the advanced rotorcraft configuration element, in which advanced technology developed at the systems level is

integrated into a demonstration vehicle for full scale in-flight proof-of-concept. There are four active research and development rotorcraft flight programs; the Model 360 Advanced Technology Helicopter, the Advancing Blade Concept (ABC), the Tilt-Rotor Research Aircraft, and the Rotor Systems Research Aircraft (RSRA)/X-Wing Rotor Program.

The Model 360 program involves a Boeing-Vertol effort in developing an all composite aircraft that will feature a number of advanced systems in order to achieve a payload capacity increase of 25 per cent, improved hover performance, and a greater cruise efficiency to speeds greater than 200 knots. The Sikorsky ABC aircraft has successfully demonstrated forward speeds of more than 250 knots in a research program sponsored by the U.S. Army and involving Sikorsky, the U.S. Navy, and NASA. The aircraft uses counterrotating main rotor blades to overcome the problem of retreating blade stall and may have potential as a small, compact, quiet, public service helicopter for operations in residential areas.

The Tilt-Rotor aircraft also attacks the high speed requirement and has been successfully demonstrated in the Bell Helicopter XV-15 Tilt-Rotor Research Aircraft. Two of these aircraft were built under a joint NASA/U.S. Army program. The potential benefits of the tilt rotor include the ability to conduct missions at twice the speed and range

of the conventional helicopter using a given quantity of fuel. The implications for military and civil use are significant, and the program has found military funding as the Navy JVX program (with Bell and Boeing-Vertol being teamed for development).

The last and most ambitious configuration program is the X-wing configuration, which has a design speed goal of 400 to 500 knots. The X-wing rotor acts like a helicopter rotor in hover and low speed flight and is then locked in a fixed position while accelerating to high speed forward flight with an auxiliary propulsion system. The design incorporates Circulation Control Rotor (CCR) technology that enables the rotor to perform the dual function of a helicopter rotor when rotating and a fixed wing when stopped. The X-wing rotor will be investigated in a joint NASA/DARPA proof-of-concept flight program using the RSRA, with the primary objective being the investigation of the conversion from rotary-wing flight to fixed-wing flight. [1:231]

C. MILITARY DEVELOPMENTS

In the past, military requirements have led to the introduction of new capabilities into the civil market place, notable examples being the Bell UH-1, the Bell OH-58, the Hughes OH-6, and the Boeing-Vertol CH-47. It is likely that the current UH-60 Black Hawk and CH-53 Sea Stallion series will present civil opportunities, although operating

economies have not yet justified that transition. Emerging military programs, however, may have a much greater significance for the future of civil helicopters.

1. The Joint Services Advanced Vertical Lift Aircraft (JVX)

The JVX is multimission vertical-take-off-and-landing tilt-rotor aircraft. The design uses the advanced, mature technology proven in the Bell Helicopter XV-15 program supported and managed jointly by the Army and NASA. Bell is teamed with Boeing-Vertol for preliminary design and development. It is expected to go into operation in 1992 with a production of over 500 aircraft. It will have a gross weight in excess of 40,000 lbs., a maximum cruise speed of 350 knots at an altitude of 17,000 feet, and the capacity to move thirty assault troops on missions with up to a 250 mile radius. This vehicle will have twice the speed, range and altitude of the conventional helicopter of today, and will be self-deployable throughout the world. The design of the JVX incorporates a number of advanced technologies (composite materials, advanced digital flight control systems and aerodynamic, aeroelastic, and crash-worthiness design methods demonstrated in other government and industry research and development programs). This program could well lead to the development of civil transport configurations in the late 1990s (e.g., to transport 30 passengers 300 nautical miles in one hour, execute a vertical

landing and take-off and return with thirty passengers without refueling). This capability also creates many opportunities for further applications, including off-shore oil rig support (where new fields are beyond the range of current helicopters), and inter-city and regional transportation.

[1:235]

2. The U.S. Army Light Helicopter LHX Family

The LHX program is part of a U.S. Army program to reduce its inventory of operational helicopters from in excess of 22 aircraft models to 7 aircraft models by the year 2000. The LHX family involves replacement of four U.S. Army helicopters (the Bell OH-58 Kiowa Scout helicopters, the Bell AH-1 Cobra gunships, the Bell UH-1 Iroquois utility transports, and the Hughes OH-6 Cayuse Scout helicopters) and is intended to be deployed progressively from the late 1990s. It will be developed in two basic configurations: a light utility version designated the LHX-UH, and a scout/light attack version designated the LHX-SCAT. It will complement the Bell AHIP Advanced Scout Helicopter (a significantly modernized OH-58 designated the Model 406 by Bell and the OH-58D by the Army), the Sikorsky UH-60 Black Hawk assault transport helicopter, and the Hughes AH-64 Apache helicopter, all of which will remain in service into the twenty-first century. [32:585]

Initial studies have focused on the feasibility of the single pilot cockpit, and a significant feature is the

emphasis being placed upon avionics architecture and subsystems integration. The LHX will be able to perform scout and attack missions with a one man crew by automating communications, navigation and target acquisition, identification, radar warning, missile detection, fire control and flight control. An Advanced Rotorcraft Technology Integration (ARTI) program initiated in 1983 is addressed to the many issues related to the integration of the available technologies into a cost effective aviation weapons system. If the ARTI and the LHX programs are successful, the sophistication of rotorcraft will be advanced dramatically, and this new technology base will provide a spring board for other military and civil applications, such as a wide variety of public service applications. Many police, fire, and emergency medical needs could be satisfied with a civil derivative of the LHX, demonstrating rapid guidance, navigation, communication and control in an all-weather environment with a one-man crew. [1:236]

This program is extremely significant for the U.S. helicopter industry, since projections are that the U.S. Army alone requires approximately 5000 units. A driving factor in the program is the Army speed requirement, yet to be finalized. All indications are that the speed requirement for cruise or dash could be as high as 250 - 300 knots. Should this be the case, the program will be driven to an

advanced high speed configuration (e.g., a downsized Bell-Boeing tilt-rotor or an appropriately sized Sikorsky ABC aircraft). A lower speed requirement would permit the submission of more conventional designs. [32:586]

3. The Advanced Cargo Helicopter (ACH-XX)

The Advanced Cargo Helicopter (ACH-XX) is in the concept definition stage. This is envisioned as a follow-on to the Boeing-Vertol CH-47 Chinook and a possible alternative to the Boeing-Vertol XCH-62 Heavy Lift Helicopter. The ultimate size and payload could well be greater than the CH-47, and its required radius of operation could well dictate a configuration other than that of a conventional helicopter.

D. THE FEDERAL AVIATION ADMINISTRATION (FAA)

The increased attention of the FAA to rotorcraft matters is a good indication of the growth potential of the helicopter industry. The FAA has established a Rotorcraft Program Office in Washington, D.C. and has recently issued a comprehensive Master Plan [Ref. 33] that outlines the many activities being performed by the FAA in its efforts to achieve acceptance of the rotorcraft as a viable means of civil aviation transport. [1:237]

The essential elements of the plan are threefold; firstly, to improve the National Airspace System to permit the rotorcraft to take maximum advantage of their unique capabilities; secondly, to provide for an adequate system of heliports,

and thirdly, to improve safety by means of more exacting criteria and technology in the airworthiness and certification process. [33:5]

Part of the program is the development of the National Prototype Demonstration Heliport program, launched with the initial selection of four large cities (New Orleans, New York, Los Angeles, and Indianapolis) where central business district prototype heliports will be built. These heliports will serve as models in the development of procedures and equipment to demonstrate the feasibility and desirability of urban area all-weather heliports, with the plan envisioning such heliports in 25 major cities by the year 2000.

[1:28]

E. CIVIL APPLICATIONS

1. Air Transportation

Corporate and business rotorcraft represent a growing segment of the helicopter market. Currently, helicopters perform adequately for ranges of 10 to 30 miles, and fixed-wing aircraft suffice for 200-400 mile trips. The growth of the extended-range, more cost-effective helicopter may well fill the ill-defined range from 30 to 200 miles. The development of scheduled rotorcraft services will depend on aggressive operators, the availability of reliable equipment, and, most importantly, the achievement of a significant reduction in operating costs. The spin-offs from the emerging military technology could well provide these benefits.

Continued development of quiet, economical, all-weather, extended-range vehicles could permit the growth of civil helicopter transportation by the turn of the century.

[31:II-1]

2. Forestry and Agriculture

As timber costs have risen, it has become more cost-effective for timberland owners and managers to invest in helicopters to perform a wide range of forestry tasks. Helicopters are more efficient and more precise than fixed-wing aircraft and the Forestry Service alone now employs more than 140 helicopters to fight forest fires. Because of their superior performance, helicopters are expected to make greater inroads into the agricultural market (especially as operating costs are reduced by the introduction of more efficient technology. [31:II-2]

3. Resource Exploration and Development

This is perhaps one of the most promising areas for future market development. Most of the natural resources of the world are located in remote areas where access by ground transportation is difficult. The helicopter is a vital link in the search for and production of oil, and can be used for delivering men and equipment to rigs, constructing and servicing pipelines, and moving entire rigs. As the search for oil moves farther off-shore, the development of the extended-range helicopter being promised by current military programs will broaden the civil market substantially.

4. Construction

Helicopters are used in half the power line construction in Canada and about ten percent of that in the United States. The potential for reducing the costs of installing heavy equipment is considerable, particularly in remote locations. The technology has not been well developed in the free world but recent military developments, such as the refunding of the XCH-62 Boeing-Vertol Heavy Lift Helicopter and the planned development of the ACH-XX Advanced Cargo Helicopter may well bring that technology to the market place.

5. Public Service

More than sixty-five cities and twenty states use helicopters for police work because their response time is less and their surveillance capabilities are greater than those of ground units. More and more communities are using a helicopter ambulance service in connection with emergency medical care. Helicopter teams with heliports at trauma centers are now being supported by those communities.

The potential users of such helicopters specified high speed, long endurance, modular design, and low levels of noise and vibration among the many attributes desired in a public service helicopter. All these criteria are apparent in the technology thrusts outlined earlier in this chapter.

[1:242]

F. THE FUTURE MARKETS-FORECASTS

Considered by many as the low point of a helicopter sales slump, 1983 saw civil deliveries by U.S. firms fall to 415 units, arresting the rapid rise that ended with a 1980s peak of 1,366, whilst the value of those shipments declined from \$656 million in 1981 to \$283 million in 1983. What hit the industry hard in that period was an unprecedented downturn in helicopter usage, due in large part to the world wide recession but also affected by other diverse factors ranging from fuel conservation to the U.S. Department of Agriculture's payment in kind program. As 1984 began, the economic indicators all pointed to a strong recovery from the difficulties of the first three years of the decade but with perhaps a more controlled growth rate than that experienced in the 1970s [34:5].

Many annual projections of helicopter sales are produced, but perhaps the most respected is from Allison Gas Turbine Operations of General Motors. A recent projection by Allison predicted free world helicopter sales of 22,500 units during the next ten years, compared with 19,000 units for the preceding decade, with almost two-thirds of the sales being commercial. (See Table 6) According to the Allison forecast, commercial deliveries will increase 29.2 percent in 1984 through 1993 (13,700 units compared to 10,600) while military deliveries will increase 4.7 percent (8,800 units

TABLE 6

FREE WORLD HELICOPTER DELIVERIES (UNITS)

	<u>1974-1983</u>	<u>1984-1993</u>
NORTH AMERICA	8,000	13,000
FOREIGN	<u>11,000</u>	<u>9,500</u>
TOTAL	19,000	22,500
<hr/>		
CIVIL	10,600	13,700
MILITARY	<u>8,400</u>	<u>8,800</u>
TOTAL	19,000	22,500

compared to 8,400). Allison also predicts North American unit sales to increase by 62.5 percent compared to a decade ago, while predicting that foreign sales will decline by 13.6 percent. Allison maintains that the continued growth in helicopter sales will be driven by a number of factors, including the desire of operators to re-equip with new technology aircraft, a change from piston to turbine power plants, and the increasing desire for twin turbine helicopters. [34:6]

In a further forecast, Bell Helicopter produced a "consensus" forecast, developed from an aggregation of a number of industry forecasts. This forecasts predicts that between 20,000 and 24,000 units will be delivered between 1982 and 1991, with values ranging from \$59.9 billion to

\$69.4 billion. It can be seen that these figures are reasonably consistent with the Allison forecast. [34:6]

Essential to these forecasts are predictions and trends for a number of industries. Principal among these is the oil industry. A study by the Hughes Tool Company [34:6] demonstrated a good correlation between the "annual U.S. oil rigs operating" count and the number and value of civil helicopter shipments by U.S. firms. In their annual forecasts, oil industry trade magazines have indicated considerable potential for growth in Indonesia, China, India, and Ireland, where off-shore oil was discovered in 1983. Explorations in Norway is also moving farther northward, with wells in 1983 above 71 degrees latitude. [34:6]

Corporate usage is assessed somewhat more confidently. Interest rates, once a major stumbling block, have come down to more manageable levels, and the overall upturn in the economy may lead to corporations previously concerned about stockholder reaction to a proposed helicopter purchase now determining to consider such an acquisition. The availability of twin engine helicopters has also made this market more promising owing to the increased safety margins. [34:6]

Sikorsky Aircraft, in a press release dated 20 January, 1984, forecast a robust 23 percent increase in the world helicopter market for the period 1983-1993, compared with the previous ten-year period. Sikorsky predicted that, despite the forecast of an almost even split (military/

civil) in terms of units sold, the revenues from the military market will be almost three times those of the civil market, indicating that future military procurements will involve heavier and more sophisticated helicopters than the civil sector. The military market will be driven by the replacement of the aging military helicopter fleets of the world with newer, more capable aircraft, plus the growth of rapid deployment forces and a heightened awareness of the capability of the helicopter in various military roles. Sikorsky further predicted the greatest production growth in the intermediate weight category, where much of the demand will come from a rebound of the off-shore oil market, the corporate/executive market, and the public service market, the growth being facilitated by performance improvements and the FAA's efforts to create a nationwide heliport system. They also predicted that the light helicopter market will grow by ten percent a year during the next ten years, with over 8,000 units being sold (both single and twin engined) and with the average price increasing from \$600,000 to \$750,000 in constant 1983 dollars (reflecting the increased helicopter sophistication requirements of operators). The Sikorsky projections are summarized in Table 7.

TABLE 7

SIKORSKY TEN-YEAR PROJECTION - CIVIL HELICOPTERS

(UNITS)

	U.S.	REST OF FREE WORLD	TOTAL
SEGMENT			
LIGHT (0-7000 lb.)	4,700	3,500	8,200
INTERMEDIATE (7-15,000 lb.)	1,000	1,200	2,200
MEDIUM/HEAVY (Above 15,000 lb.)	200	300	500
TOTAL	5,900	5,000	10,900

G. COMPETITIVE SITUATION

It is no mistake that the major survivors in the U.S. helicopter industry are Bell, Boeing-Vertol, Sikorsky, and Hughes. All have achieved considerable success through the years and all apart from Hughes were involved in the U.S. industry from its birth in the 1940s. Sikorsky and Hughes have full military order books with committed and approved programs for the Sikorsky Black Hawk series and the Hughes AH-64 Apache attack helicopter, respectively. Bell and Boeing-Vertol both have modernization programs for the OH-580 (AHIP) and the CH-46/CH-47 transports, and are teamed for development and production of the JVX program for the U.S. Navy/Marine Corps. On the civil side, Bell and Hughes

have successful helicopters in the light and intermediate corporate/executive/EMS/public service helicopter markets and are continuing to target those sectors with model upgrades to their existing range. It is interesting to note that of the major world helicopter manufacturers, Agusta, Bell and MBB are currently each involved in two development programs committed to production. Three others, Aerospatiale, Boeing-Vertol, and Westland, are each involved in one. Sikorsky and Hughes, having just entered production with major new military programs, do not have any current development programs committed to production. [35:66]

According to John Zugschwert, the Executive Director of the American Helicopter Society, research airframe programs are important when forecasting the future of the helicopter industry. Of the major U.S. manufacturers, Sikorsky has three (Rotor Systems Research Aircraft, Advancing Blade Concept, and Advanced Composite Airframe Program), Bell has two (XV-15 tilt rotor and Advanced Composite Airframe Program), Boeing-Vertol has one (the Heavy Lift Research Vehicle), and Hughes has one (the No-Tail-Rotor (NOTAR) concept). [35:67]

Zugschwert also points out that there will not be a major new program entering production until the Agusta A-129 in 1988, some seven years since the Sikorsky Black Hawk and the Hughes Apache in the early 1980s. The one possible

exception to this is the Bell AHIP which is in reality a major OH-58 modification which also signals the introduction of the first new commercial production since the MBB BK-117 in the early 1980s (the AHIP technology will be used in the production of the Bell 400 series light twin commercial helicopter to be built in Canada). [35:68]

A period of some import for the industry will be the 1990/91 timeframe when a number of new production starts are planned, including the Aerospatiale/MBB PAH-2 Franco-German anti-tank helicopter, the Agusta/Westland EH-101 civil/military helicopter, the U.S. Marine's JVX developed by the Bell/Boeing-Vertol team, and possibly the MBB/Hindustan Advanced Light Helicopter. These starts indicate the strength of the participants, and the long term implications of the European cooperative programs should not be overlooked. Finally, the LHX program for the U.S. Army is scheduled for production in the mid 1990s and is currently being competed for by Bell, Boeing-Vertol, Hughes, Sikorsky, and IBM. The presence of IBM in this competition should be no surprise, as they were the successful prime contractor in the U.S. Navy Sea Hawk ASW helicopter competition, with Sikorsky (the airframe manufacturer) being relegated to the position of sub-contractor.

It is further apparent that every development program is government funded and designed solely for military use, with the exception of the EH-101 (being designed from the

outset as a civil and military helicopter), and possibly the MBB/Hindustan Advanced Light Helicopter. The current research programs all started back in the 1970s and their technology will be spent by the 1990s. [35:68]

John Zugschwert finally states:

On the civil side, it appears that 1950 airframes will still be around at the turn of the century. While many new helicopters entered development in the 1970s, i.e., the complete Aerospatiale line, the Bell 412, the Bell 214ST and 222, the Boeing-Vertol 234, the Hughes 500 series, the MBB BK-117, the Sikorsky S-76 and S-70, and the Westland W-30 series--it appears that civil users and operators are waiting again for a lead from the military to find the markets to support commercial production of commercial-designed helicopters. The only new production appears to be the Bell 400 series and the EH-101. The fact that the military has initiated major production programs should indicate that the major commercial fall-out should take effect by the mid 1990s. [35:68]

Remembering that the major programs referred to are the LHX and the JVB, it is easy to see that the relative future positions of the major U.S. helicopter firms will be determined by the contract awards of these two programs. Bell and Boeing-Vertol have already secured the final two places in the JVB program. The LHX program, with all the major U.S. firms anxious to bid, appears to be the determining factor in the future structure of the U.S. helicopter industry.

X. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

The objective of this thesis has been to determine the critical factors that have influenced the evolution of the U.S. helicopter industry. The research indicated that the most significant influence on the industry was the involvement of the U.S. DoD in providing both R and D funds and quantity production contracts. The Korean and Vietnam conflicts played a large part in generating the military requirements in the 1950s and 1960s and provided the basis for the emerging generation of military helicopters in the 1980s.

The increasing competition from the European helicopter manufacturers has had a considerable impact on the recent nature of the industry. The U.S. helicopter market has moved from a predominantly military market to one that is being increasingly penetrated by civil helicopters and the U.S. manufacturers are being threatened in the domestic civil helicopter market by Aerospatiale.

The most significant technological influence has been the introduction of the light turbine engine that opened the market for the small commercial helicopter, particularly in response to a market demand for economical and productive helicopters for oil rig support.

The following sections summarize, in some more detail, the main conclusions of the research effort, in a format that corresponds to the research questions listed in Chapter I. The chapter concludes with some recommendations for further study.

B. CONCLUSIONS

1. U.S. Military Customers/Markets

a. The U.S. military helicopter market was established in the Korean War. The French experience in Indo-China and Algeria demonstrated the viability of the combat helicopter but the real transition from logistic support and rescue helicopters to military combat helicopters occurred with the Vietnam conflict in the 1960s when the American industry expanded dramatically to produce the huge surge of requirements that peaked in 1968.

b. U.S. military orders declined rapidly in the post-Vietnam period as the DoD re-developed strategy in the light of the Vietnam combat experience. Military orders did not appear in any substantial quantity until the late 1970s with the introduction of a new range of assault, anti-tank, and ASW helicopters emphasizing survivability and integrated avionics systems.

c. The next generation of military helicopters will be replacements for much of the existing helicopter inventory and will involve substantial quantity production of the JVX

Vertical Lift Helicopter and the LHX Light Helicopter, both due to enter service in the 1990s.

d. The military market has proved to be highly volatile and cyclical, with major new programs emerging on average about every 10 to 15 years, with each contract being subject to the competition requirements of the DoD. A new military program can take more than eight to ten years from conception to production. The stakes, therefore, are high, as are the risks.

2. U.S. Commercial Customers/Markets

a. The early applications of the helicopter were confined to military tasks. The first civil helicopter certification was awarded to Bell Helicopters in 1946. All the early U.S. manufacturers developed helicopters for an anticipated civil market that did not immediately eventuate.

b. Even after the Korean War, all commercial helicopters were direct derivations of military types, and civil growth was very shallow for twenty years, owing to high capital costs, high operating costs, poor payload, lack of public acceptance and awareness, and lack of all-weather capability.

c. The Vietnam War provided technological spin-offs to the civil sector. In particular, the introduction of the turbine into small 4/5 seat helicopters opened a new era in commercial helicopters.

d. The year 1970 marked the beginning of commercial helicoptering in its own right with the onset of new designs aimed at the civil market, mainly in the small single turbine-engined 4/5 seat executive helicopter. The private market began to expand at the same time.

e. Technology derived from military programs advanced the civil helicopter both in design and economics of operation, and manufacturers embarked on aggressive marketing tactics to develop new markets.

f. As a result of these tactics, civil market growth has been steady in the corporate, commercial, and public service applications. A major emerging market for the light and intermediate helicopter has been the oil rig support market, following the oil exploration boom of the 1970s.

g. Whilst civil sales declined in the early 1980s due mainly to the worldwide recession, the prognosis is for continued civil helicopter market growth, although the major U.S. market thrust continues with technologies derived from military programs.

h. Medium and heavy helicopters have not yet achieved cost-competitive acquisition and operating economics, and therefore, civil helicopter market penetration has been achieved by makers of light and intermediate helicopters. For this reason, airline usage of helicopters has not developed, and is not likely to do so in the immediate future.

3. Military Requirements

a. U.S. military requirements have historically been the source of R and D funds for the helicopter industry.

b. The U.S. military has become increasingly specific in stating helicopter requirements. In the past, military requirements have dictated the commercial helicopter product line as the manufacturers have sought to minimize the business risk associated with civil helicopters by deviating minimally from military designs.

c. In the U.S., civil and military technology is and will continue to diverge, with military systems stressing maneuverability and survivability technologies whilst civil technologies will stress economy and comfort. Military funded technology is becoming less applicable to civil developments, requiring manufacturers to seek other sources of funds for civil R and D. These factors are particularly applicable in the medium and heavy markets where the helicopters are highly specialized and sophisticated. Thus, the heavy helicopter manufacturers are more dependent on military contracts for continuing workload whereas the light helicopter manufacturer can more easily produce a civil/military mix.

d. The military requirements are volatile and cyclical in nature. A changed military strategy can spell doom for a manufacturer who is committed to a unique state-of-the-art design concept (e.g., the Lockheed Cheyenne

AAFSS helicopter program was destroyed by changing Army Strategy).

e. Military acquisition cycles are long and bureaucratic and usually involve intense competition. A military helicopter manufacturer must be able to sustain a substantial resource investment over a long period in order to survive.

4. U.S. Competitors

a. The major surviving U.S. firms are Sikorsky, Boeing-Vertol, Bell, and Hughes. Sikorsky and Boeing-Vertol (then Piasecki) focused on medium and heavy helicopters, with Sikorsky producing single rotor helicopters and Boeing-Vertol tandem rotor helicopters. The Sikorsky approach has been more successful and became the worldwide standard configuration. The Boeing-Vertol tandem rotor design had unique advantages for certain applications, however, and it has secured a niche in the medium/heavy lift transport helicopter market.

b. Bell and Hughes have concentrated on the relatively simple and inexpensive light and intermediate helicopters that are easier to commercialize from military designs. Whilst the profit margins on these helicopters are not as great, the access to the civil market gives a greater sales volume potential and provides some protection against the cyclical DoD workload by providing low overhead civil work.

c. In general, the surviving firms have possessed most of the following characteristics:

- (1) A focused and differentiated marketing and product line strategy.
- (2) Corporate strength.
- (3) Financial strength.
- (4) Ability to bid on DoD R and D contracts.
- (5) Ability to win DoD R and D contracts.
- (6) Ability to win military production contracts.
- (7) Ability to commercialize helicopters from their military product lines.
- (8) A willingness to invest corporate funds in company funded R and D, noting that between 30 and 40 percent of IR and D expenditures are currently being recovered on DoD contracts.
- (9) Ability to perform on development and production contracts.
- (10) Ability to keep abreast of technology.
- (11) An awareness of the intricacies of the military procurement system and an empathy with military strategy and requirements.

d. All the survivors are part of larger corporations and therefore, have substantial corporate backing, a critical factor for survival. The majority of the firms who either failed or did not succeed dramatically did not have the financial resources to weather sustained attacks on their market share by more powerful competitors.

e. Sikorsky has assumed the dominant position in the ASW and assault helicopters whereas Hughes has secured the valuable U.S. attack helicopter market. Bell and Boeing-Vertol have no new military production, but are teamed for

the JVX tilt rotor development and will compete for production. All the four will compete for the LHX Army program, along with IBM, the only non-airframe manufacturer to bid. With the heavy emphasis on systems integration and given that IBM is now prime contractor for the Navy Seahawk LAMPS III ASW helicopter program, IBM's prospects should not be discounted.

5. Global Situation

a. The European firms took advantage of the American commitment to the Korean and Vietnam conflicts and bought U.S. technology through licensed production of American designs. Europe quickly caught up and developed indigenous designs.

b. The U.S. industry is facing increasing competition from the European manufacturers. France's Aerospatiale is producing about half of the foreign delivered helicopters. In terms of production units, deliveries by foreign manufacturers exceeded those of the U.S. manufacturers in 1982 for the first time.

c. European subsidies of helicopter manufacturers are based on objectives of creating and supporting domestic industry capability in order to achieve defense independence.

d. European domestic helicopter consumption is insufficient to sustain the industry (about 80 percent of the industry output is exported) and therefore the respective governments provide financial subsidies, favorable loan

conditions, and export subsidies in order to target the North American and third world markets (both civil and military). In the U.S. the Export-Import Bank, whose financing is available only for commercial sales, does not provide competitive rates. All four major European firms (Westland, Aerospatiale, MBB, and Agusta) have U.S. subsidiaries and MBB has announced the intention of building light helicopters in Canada for the U.S. market.

e. The European industry is virtually shutting the door on U.S. competition by embarking on a series of collaborative production arrangements (e.g., Westland/Agusta and MBB/Aerospatiale) in order to share technologies, share risks, and reduce costs. American firms have not had any significant success in breaking into the European cooperative market. The European firms are also actively entering cooperative agreements with a number of non-European countries (e.g., India, Indonesia, and Japan).

f. In order to ensure adequate export markets, the European governments subsidize civil R and D and emphasize both civil and military applications at the outset of a new model development.

6. Technology

a. The technology that has set the pace for industry development is that of the helicopter engine. The late development of suitable engines placed the helicopter industry some 30 to 35 years behind the fixed-wing industry.

The full capability of the helicopter was not realized until the introduction of the turbine engine in the 1950s following military development programs. This technology widened the range of military applications and opened up the most significant market, that of the small, light commercial/corporate helicopter.

b. Aerospatiale was first to the market with a production turbine helicopter, establishing an early position that has never been lost. Aerospatiale has continued to attack the worldwide market with a range of helicopter weights, types, and technologies.

c. The rapid expansion of the electronics industry in the 1970s led to U.S. military development programs that incorporated technologically advanced avionics systems into the turbine-powered helicopter, permitting all-weather operation and further widening the range of civil and military applications.

d. As engines became lighter and more powerful, it became possible to incorporate two turbines into the light helicopter, adding considerable safety to helicopter operations and opening the corporate market substantially.

e. Technology is not cheap. As the world helicopter market becomes more diversified and as more sophisticated equipment is incorporated to attract customers, a company must commit large investments for the extended period of

new product development. Technology advances rapidly and it is a necessity for survival to remain abreast of the state-of-the-art and to be able to apply that technology to quantity production.

f. The U.S. industry and the U.S. Government have liberal regulations regarding dissemination of non-strategic technical information. This often permits European manufacturers to bring those technologies to market in advance of the American manufacturers. The ready availability of U.S. technology has permitted the European firms to concentrate their R and D funds in key areas (e.g., fibreglass blades and rotor heads).

g. The value of the military R and D dollar to U.S. civil helicopter development is diminishing as the U.S. military helicopter becomes more highly specialized and as the DoD continues to press for state-of-the-art improvements, regardless of their potential applicability to civil derivatives. This implies a threat to the U.S. helicopter industry, since the R and D funds need to be obtained from sources that attach a higher cost of capital to their funds.

h. The European and the U.S. Governments both fund domestic military development programs. The European governments, in addition, subsidize commercial helicopter development, thus reducing the financial risk to the European manufacturers.

i. The increasing cost of R and D and technology emphasizes the earlier conclusion that corporate and financial strength are necessary prerequisites for survival in the U.S. helicopter industry.

C. RECOMMENDATIONS FOR FURTHER STUDY

This research effort addressed the range of issues influencing the evolution of the U.S. helicopter industry. During the course of the study, it became apparent that most of the areas researched are deserving of further individual and detailed study.

In particular, the following areas are recommended as being worthy of a more focused research effort on an individual basis:

- (1) the future of helicopters in civil airline usage,
- (2) the U.S. helicopter industry participation in international cooperative development and production agreements,
- (3) the impact of military procurements on the U.S. helicopter industry,
- (4) the developing threat from third world and non-European helicopter manufacturers, and
- (5) the impact of Soviet helicopter production on the free world helicopter industry and market.

APPENDIX A

TABLE A-1

FREE WORLD HELICOPTER PRODUCTION - UNITS

YEAR	U.S. TOTAL	NON-U.S. TOTAL	FREE WORLD TOTAL
1943	15	0	15
1944	120	0	120
1945	113	0	113
1946	139	0	139
1947	173	0	173
1948	154	12	166
1949	132	22	154
1950	180	32	212
1951	423	50	473
1952	1046	61	1107
1953	1063	91	1154
1954	562	103	665
1955	590	102	692
1956	898	238	1136
1957	1003	338	1341
1958	908	353	1261
1959	704	410	1114
1960	682	394	1076
1961	698	338	1036
1962	926	403	1329
1963	1160	384	1544
1964	1495	306	1801
1965	1907	364	2271
1966	2586	422	3008
1967	2938	474	3412
1968	3362	516	3878
1969	2708	589	3297
1970	2428	642	3070

TABLE A-1 Contd.

1971	2043	515	2558
1972	1769	565	2334
1973	1522	629	2152
1974	1349	804	2153
1975	1469	776	2245
1976	1121	762	1883
1977	1126	802	1928
1978	1161	652	1813
1979	1413	733	2146
1980	1591	654	2245
1981	1291	727	2018
1982	793	854	1647
1983	648	688	1306

Source: See Text, Chapter III.D.

TABLE A-2

U.S. HELICOPTER PRODUCTION HISTORY-UNITS

<u>YEAR</u>	<u>BELL</u>	<u>HUGHES</u>	<u>U.S. TOTAL</u>
1943			15
1944			120
1945			113
1946	-		139
1947	69		173
1948	67		154
1949	33		132
1950	73		180
1951	203		423
1952	425		1046
1953	369		1063
1954	181		562
1955	134		590
1956	195		898
1957	230		1003
1958	261		908
1959	235		704
1960	263	-	682
1961	213	17	698
1962	243	86	926
1963	465	163	1160
1964	812	177	1495
1965	1099	186	1907
1966	1730	333	2586
1967	2094	276	2938
1968	1806	1121	3362
1969	1831	560	2708
1970	1935	263	2428

TABLE A-2 Contd.

1971	1797	137	2043
1972	1496	155	1769
1973	1162	211	1522
1974	979	248	1349
1975	1066	214	1469
1976	753	204	1121
1977	597	336	1126
1978	644	335	1161
1979	825	394	1413
1980	826	402	1591
1981	571	326	1291
1982	292	176	793
1983	216	135	648

Source: See Text, Chapter III.D.

TABLE A-3

U.S. HELICOPTER PRODUCTION HISTORY-UNITS

YEAR	BOEING VERTOL	SIKORSKY	OTHER U.S.
1943		15	
1944		120	
1945		113	
1946	1	138	
1947	6	98	
1948	9	78	
1949	9	76	14
1950	8	19	80
1951	28	87	105
1952	120	309	192
1953	199	323	172
1954	54	217	110
1955	135	269	52
1956	180	391	132
1957	207	466	100
1958	73	423	151
1959	29	206	234
1960	13	162	244
1961	-	201	267
1962	15	232	350
1963	50	247	235
1964	86	140	280
1965	147	124	351
1966	280	159	84
1967	310	181	77
1968	212	146	77
1969	144	106	67
1970	69	124	37

TABLE A-3 Contd.

1971	25	46	38
1972	12	40	66
1973	34	41	74
1974	11	21	90
1975	33	44	112
1976	24	19	121
1977	32	25	136
1978	10	29	143
1979	16	78	100
1980	19	166	178
1981	37	185	232
1982	9	179	138
1983	2	191	104

Source: See Text, Chapter III.D.

TABLE A-4

FREE WORLD MARKET SHARE OF U.S. MANUFACTURERS

YEAR	BELL	BOEING VERTOL	HUGHES	SIKORSKY	OTHER U.S.	TOTAL U.S.
1940			NO	PRODUCTION		
1945				100		100
1950	34	4	0	9	38	85
1953	32	17	0	28	15	92
1955	19	19	0	39	8	85
1960	25	1	0	15	23	64
1965	49	6	7	5	16	83
1968	46	5	29	4	2	87
1970	63	2	9	4	1	79
1975	47	2	10	2	5	66
1980	37	1	18	7	8	71
1981	28	2	16	9	11	64
1982	18	1	11	11	8	49
1983	16	1	10	14	8	49

Source: See Text, Chapter III.D.

TABLE A-5

FREE WORLD MARKET SHARE OF EUROPEAN MANUFACTURERS

YEAR	AERO- SPATIALE	AGUSTA	MBB	WESTLAND	OTHER NON-U.S.	TOTAL W.EUROPE
1940 .			NO PRODUCTION			
1945			NO PRODUCTION			
1950	-	-	-	15	-	15
1953	1	-	-	6	1	8
1955	-	3	-	10	2	15
1960	20	7	-	7	2	36
1965	4	3	-	6	4	17
1968	3	3	-	1	6	13
1970	10	4	-	1	6	21
1975	15	7	3	3	6	34
1980	11	5	3	4	6	29
1981	14	7	5	3	7	36
1982	26	8	5	4	8	51
1983	20	9	9	4	9	51

Source: See Text, Chapter III.D.

TABLE A-6

U.S. HELICOPTER PRODUCTION-UNITS

YEAR	CIVIL	MILITARY	TOTAL
1961	378	366	744
1962	407	554	961
1963	504	672	1176
1964	579	1007	1586
1965	598	1470	2068
1966	583	2164	2747
1967	455	2448	2903
1968	522	2880	3402
1969	534	2165	2699
1970	482	1944	2426
1971	469	1587	2056
1972	575	1312	1887
1973	770	808	1578
1974	828	506	1334
1975	864	601	1465
1976	757	348	1105
1977	848	273	1121
1978	904	166	1070
1979	1019	158	1177
1980	1366	189	1555
1981	1072	158	1238
1982	587	168	755

Source: Aerospace Facts and Figures - Various Years

Note: Does not include foreign military sales.

TABLE A-7

U.S. HELICOPTER PRODUCTION-DOLLARS MILLIONS

YEAR	CIVIL VALUE	MILITARY FLY-AWAY VALUE	TOTAL
1965	39	490	529
1966	40	749	789
1967	43	962	1005
1968	57	905	962
1969	75	845	920
1970	49	694	743
1971	69	469	538
1972	90	396	486
1973	121	268	389
1974	189	206	395
1975	274	359	633
1976	285	384	669
1977	251	316	567
1978	328	225	553
1979	403	219	622
1980	656	516	1172
1981	519	825	1404
1982	365	894	1259

Source: Aerospace Facts and Figures - Various Years

Note: Does not include Foreign Military Sales.

TABLE A-8

U.S. MANUFACTURERS' SHARE OF U.S. PRODUCTION

YEAR	BELL	BOEING VERTOL	HUGHES	SIKORSKY	OTHER U.S.
1943					
1944					
1945					
1946				100	
1947	40	3		57	
1948	43	6		51	
1949	25	7		57	11
1950	41	4		11	44
1951	47	7		21	25
1952	41	11		30	18
1953	35	19		30	16
1954	32	10		38	20
1955	23	23		45	9
1956	22	20		43	15
1957	23	21		46	10
1958	29	8		46	17
1959	33	4		30	33
1960	38	2		24	36
1961	31	0	2	29	38
1962	26	2	9	25	38
1963	41	4	14	21	20
1964	54	6	12	9	19
1965	57	8	10	7	18
1966	67	11	13	6	3
1967	71	11	9	6	3
1968	55	6	33	4	2
1969	68	5	21	4	2
1970	79	3	11	5	2

TABLE A-8 Contd.

1971	88	1	7	2	2
1972	84	1	9	2	4
1973	76	2	14	3	5
1974	72	1	18	2	7
1975	72	2	15	3	8
1976	67	2	18	2	11
1977	53	3	30	2	12
1978	56	1	29	2	12
1979	58	1	28	6	7
1980	53	1	25	10	11
1981	42	3	24	14	17
1982	37	1	22	23	17
1983	33	0	21	30	16

Source: See Text, Chapter III.D.

TABLE A-9

HELICOPTERS IMPORTED/EXPORTED-UNITS

<u>YEAR</u>	<u>IMPORTS</u>	<u>EXPORTS</u>
1963		123
1964		N/A
1965		177
1966		N/A
1967	10	223
1968	1	240
1969	3	265
1970	5	280
1971	34	296
1972	12	254
1973	44	428
1974	41	395
1975	36	336
1976	42	315
1977	56	321
1978	78	368
1979	91	459
1980	207	525
1981	213	453
1982	184	254
1983	135 ¹	255 ¹
1984	130 ²	245 ²

¹Estimate²ForecastSource: Aerospace Facts and Figures, Various Years

TABLE A-10

HELICOPTERS IMPORTED/EXPORTED-VALUE

YEAR	IMPORTS \$ MILL	EXPORTS \$ MILL
1963	-	9.8
1964	-	N/A
1965	-	16.2
1966	-	N/A
1967	0.2	25.2
1968	0	32.3
1969	0.02	30.8
1970	0.04	35.0
1971	4.5	45.3
1972	1.8	50.3
1973	8.0	83.3
1974	8.1	109.6
1975	6.9	104.6
1976	4.4	113.4
1977	18.1	105.5
1978	28.0	155.7
1979	21.6	206.6
1980	54.8	298.7
1981	105.4	346.5
1982	84.9	206
1983	110.0 ¹	220 ¹
1984	120.0 ²	230 ²

¹Estimate²ForecastSource: Aerospace Facts and Figures - Various Years

TABLE A-11
CIVIL HELICOPTERS IMPORTED BY ORIGIN-UNITS

YEAR	FRANCE	GERMANY	ITALY	OTHER	TOTAL
1977	42	11	2	-	55
1978	61	-	7	1	74
1979	81	5	4	-	90
1980	167	9	1	-	177
1981	193	12	8	-	213
1982	167	15	1	1	184

Source: Aerospace Facts and Figures-Various Years

TABLE A-12

HELICOPTERS IMPORTED BY ORIGIN-DOLLARS MILLION

<u>YEAR</u>	<u>FRANCE</u>	<u>GERMANY</u>	<u>ITALY</u>	<u>OTHER</u>	<u>TOTAL</u>
1977	13.0	4.0	1.1	-	18.1
1978	22.8	-	4.9	0.3	28.0
1979	17.3	1.3	3.0	-	21.6
1980	48.4	4.4	1.1	-	53.9
1981	92.4	6.9	6.1	-	105.4
1982	74.2	8.9	1.1	0.7	84.9

Source: Aerospace Facts and Figures-Various Years

TABLE A-13

CIVIL HELICOPTER USAGE (U.S., CANADA, PUERTO RICO)

YEAR	COMMERCIAL	CORPORATE EXECUTIVE	CIVIL GOVT.	TOTAL
1960	705	134	97	936
1961	882	173	124	1179
1962	994	213	112	1319
1963	1157	218	122	1497
1964	1333	311	123	1767
1965	1537	401	115	2053
1966	1699	475	144	2318
1967	1764	487	187	2438
1968				
1969	2390	770	273	3433
1970				
1971	2605	802	467	3874
1972	2992	745	448	4185
1973	3295	780	526	4601
1974	3418	778	623	4819
1975	3342	1056	824	5222
1976	3702	1392	1087	6181
1977	4294	1578	1288	7160
1978	4904	1891	1288	8023
1979				
1980	5581	1635	1360	8575
1981				
1982	5874	1728	1282	8884

Source: Aerospace Facts and Figures, Various Years

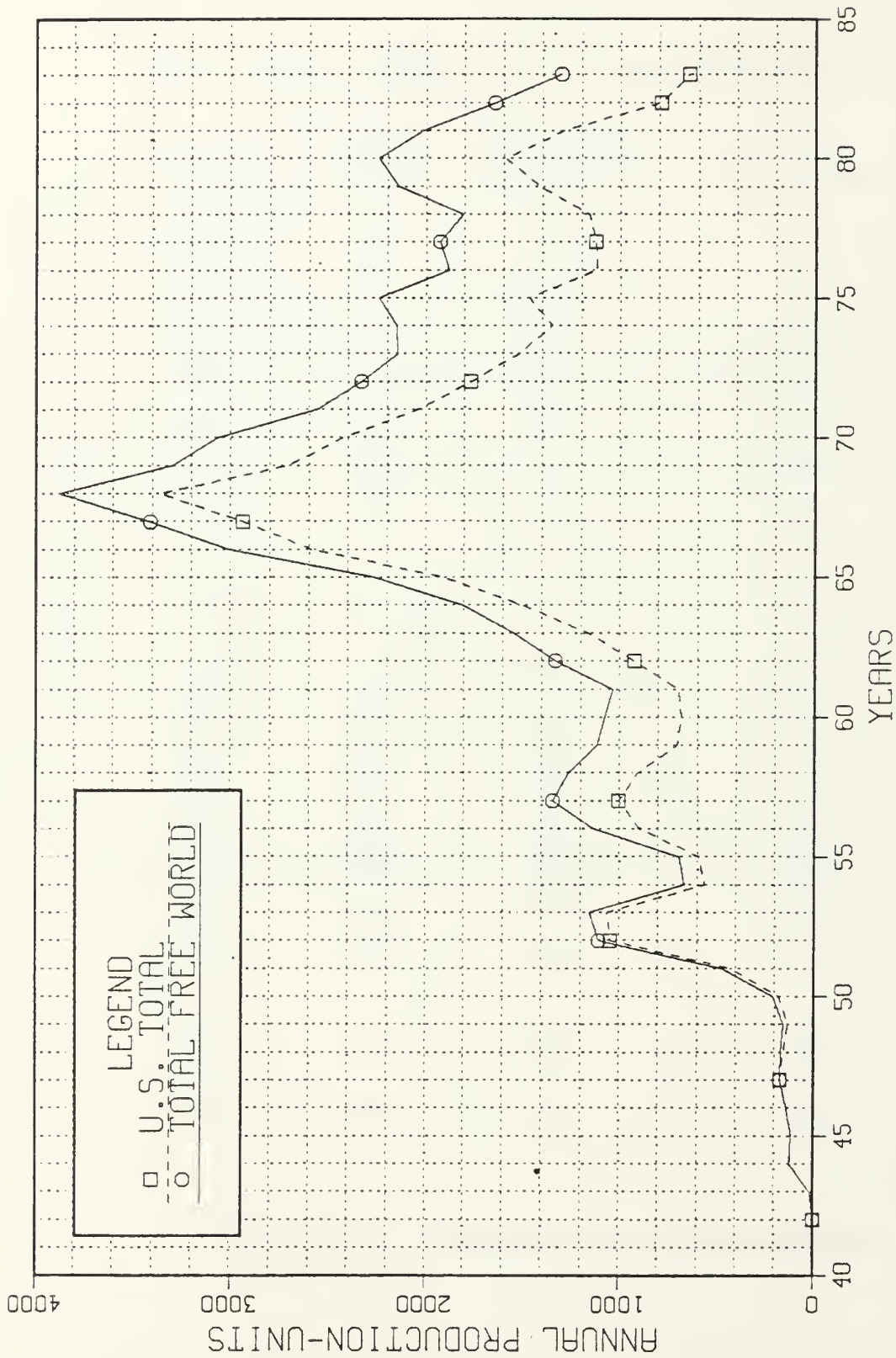


Figure B-1. Free World Helicopter Production - Units.

Source: See Text, Chapter III.D.

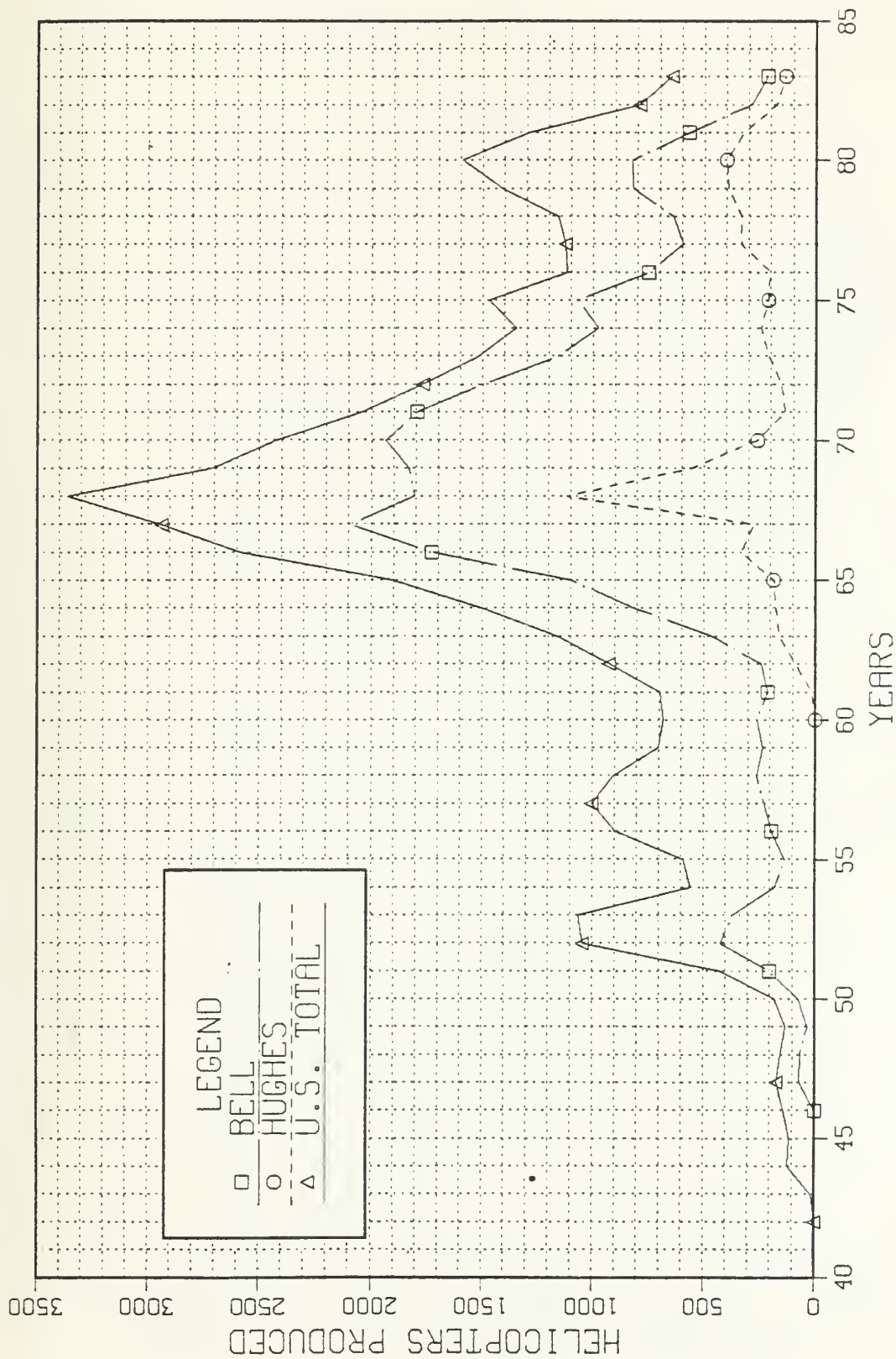


Figure B-2. U.S. Helicopter Production - Units.

Source: See Text, Chapter III.D.

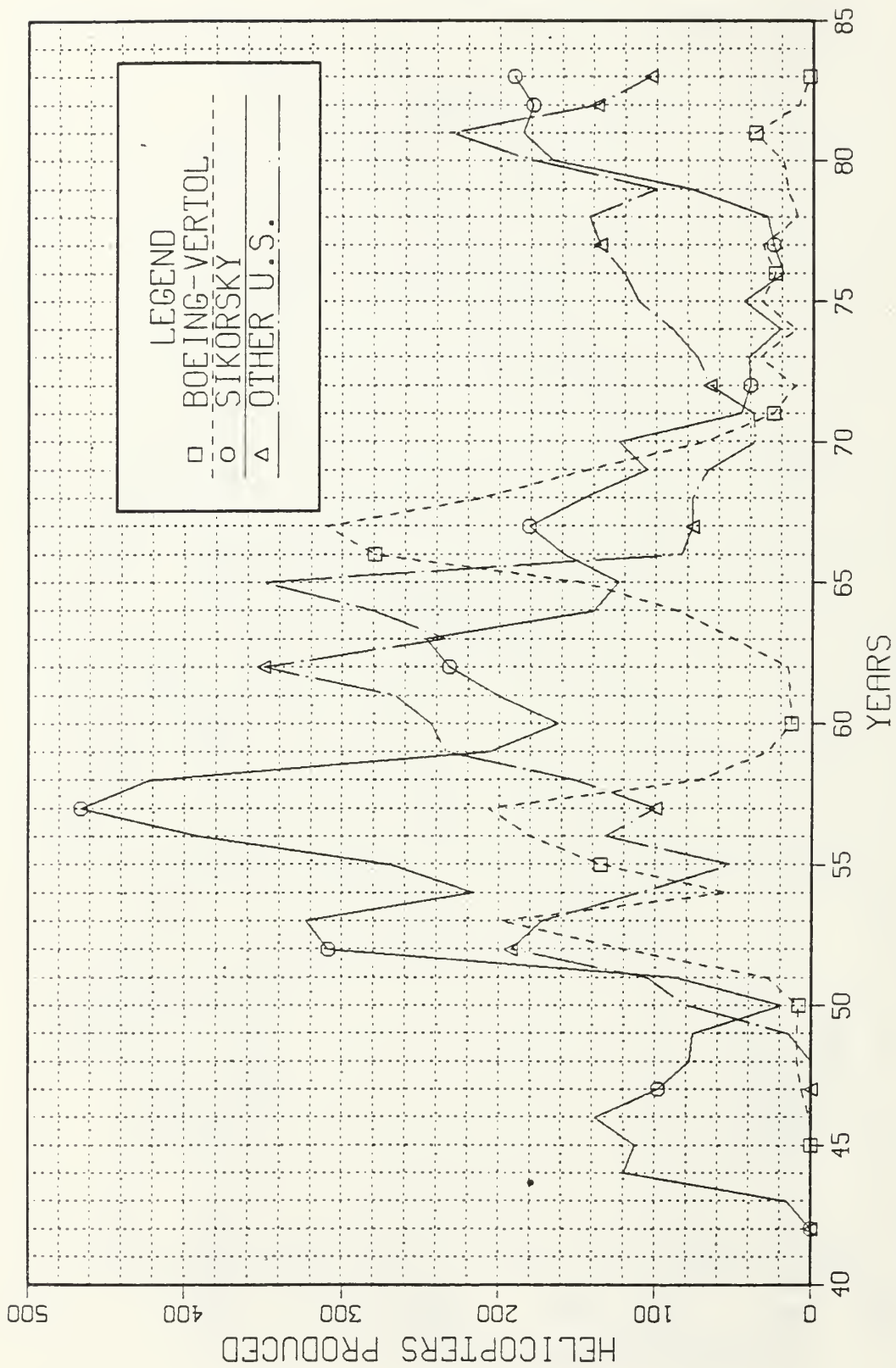


Figure B-3. U.S. Helicopter Production - Units.
Source: See Text, Chapter III.D.

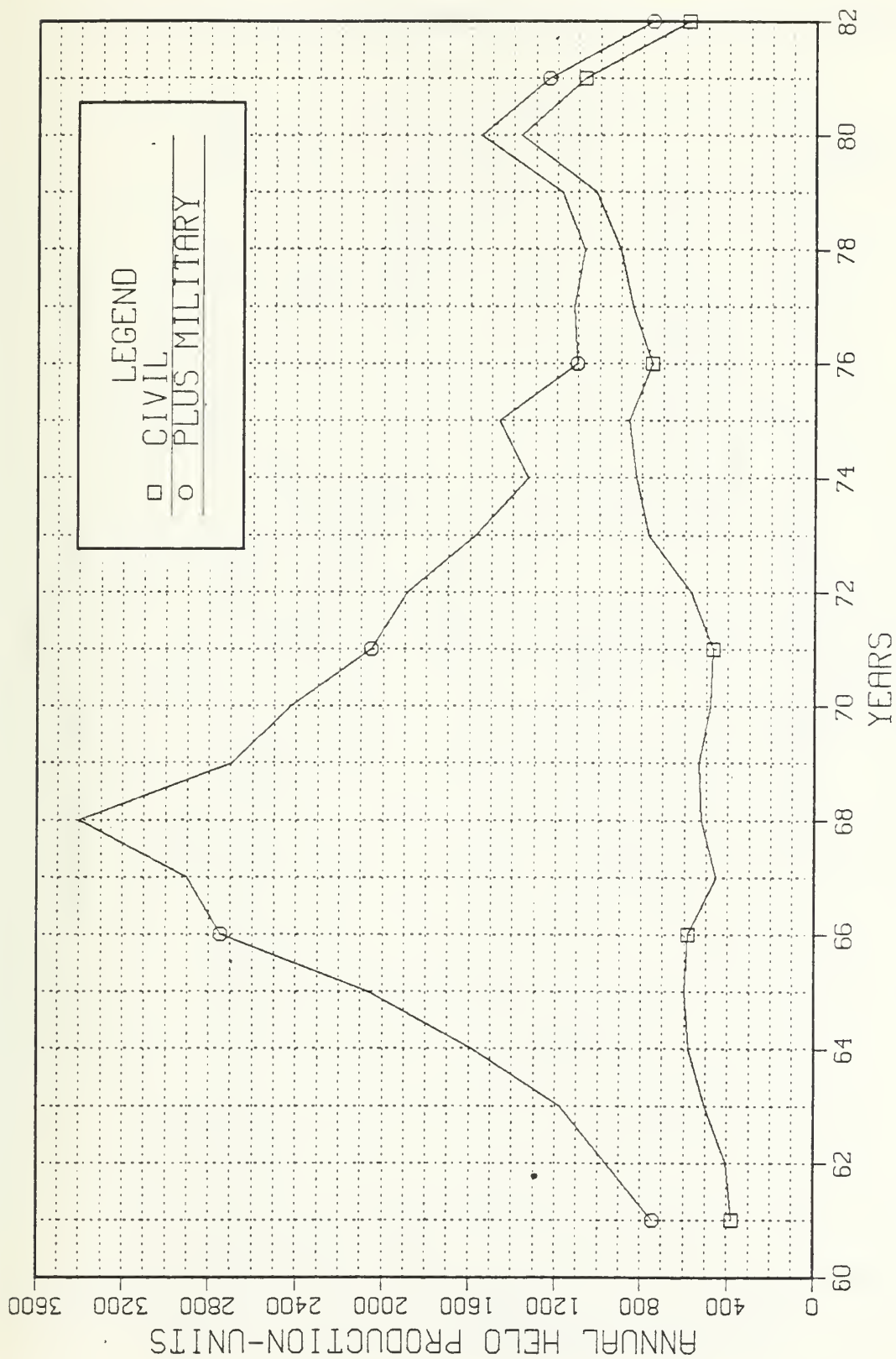


Figure B-4. U.S. Helicopter Production - Units

Source: Aerospace Facts and Figures, various years.

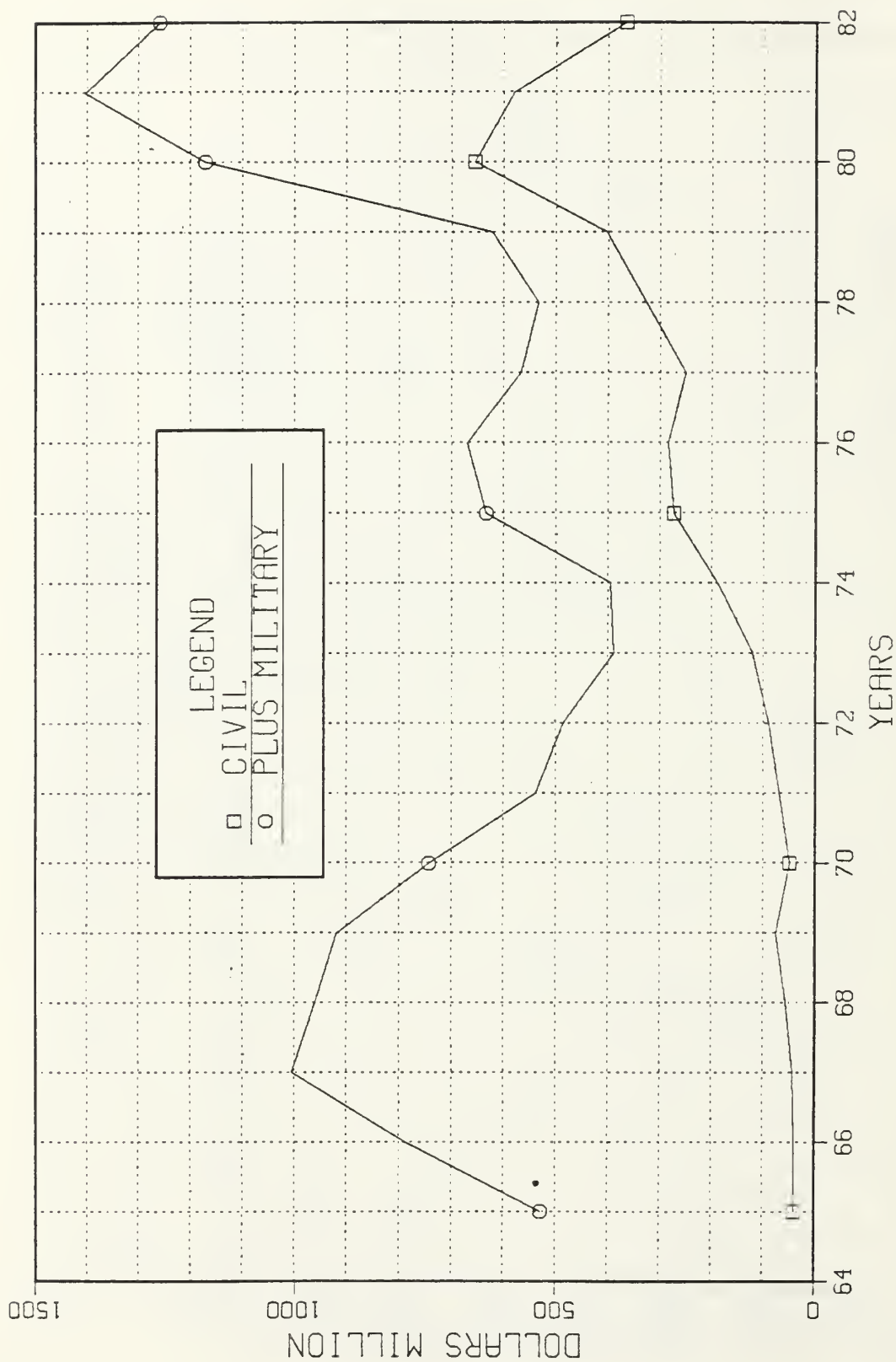


Figure B-5. U.S. Helicopter Production - Dollars Million.

Source: Aerospace Facts and Figures, various years.

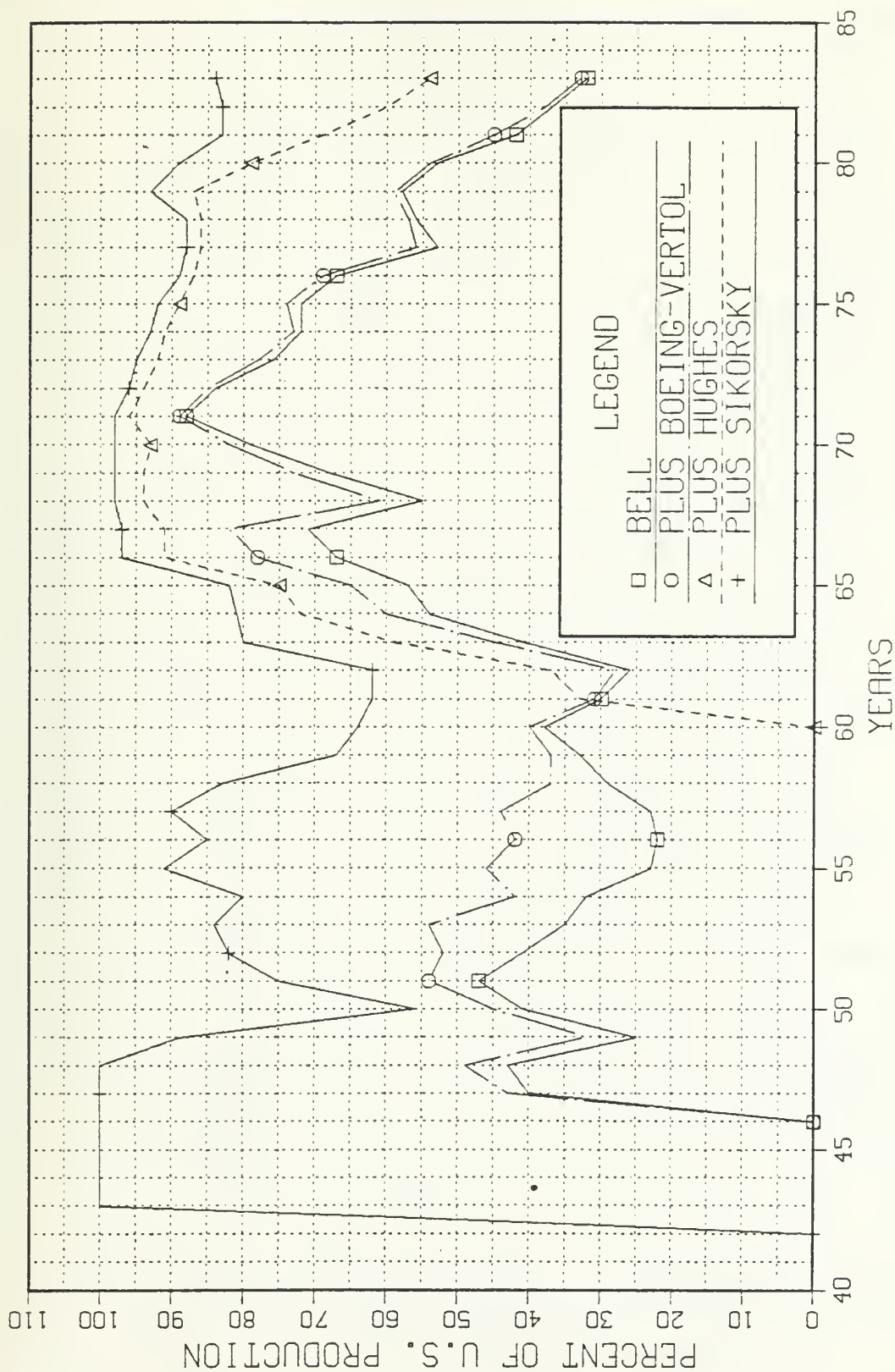


Figure B-6. U.S. Manufacturers Market Share of U.S. Production.

Source: See Text, Chapter III.D.

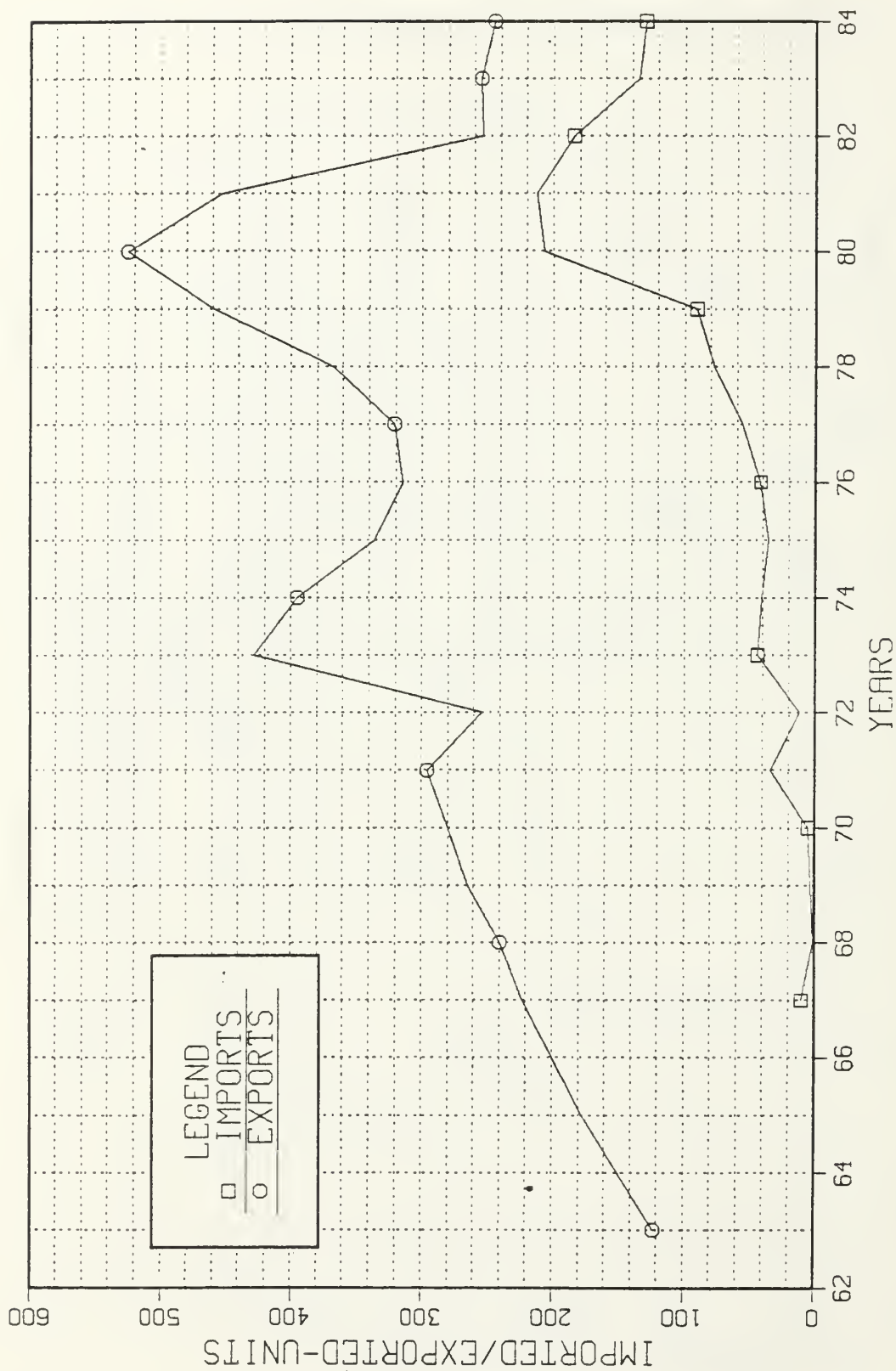


Figure B-7. Helicopters Imported/Exported - Units.

Source: Aerospace Facts and Figures, various years.

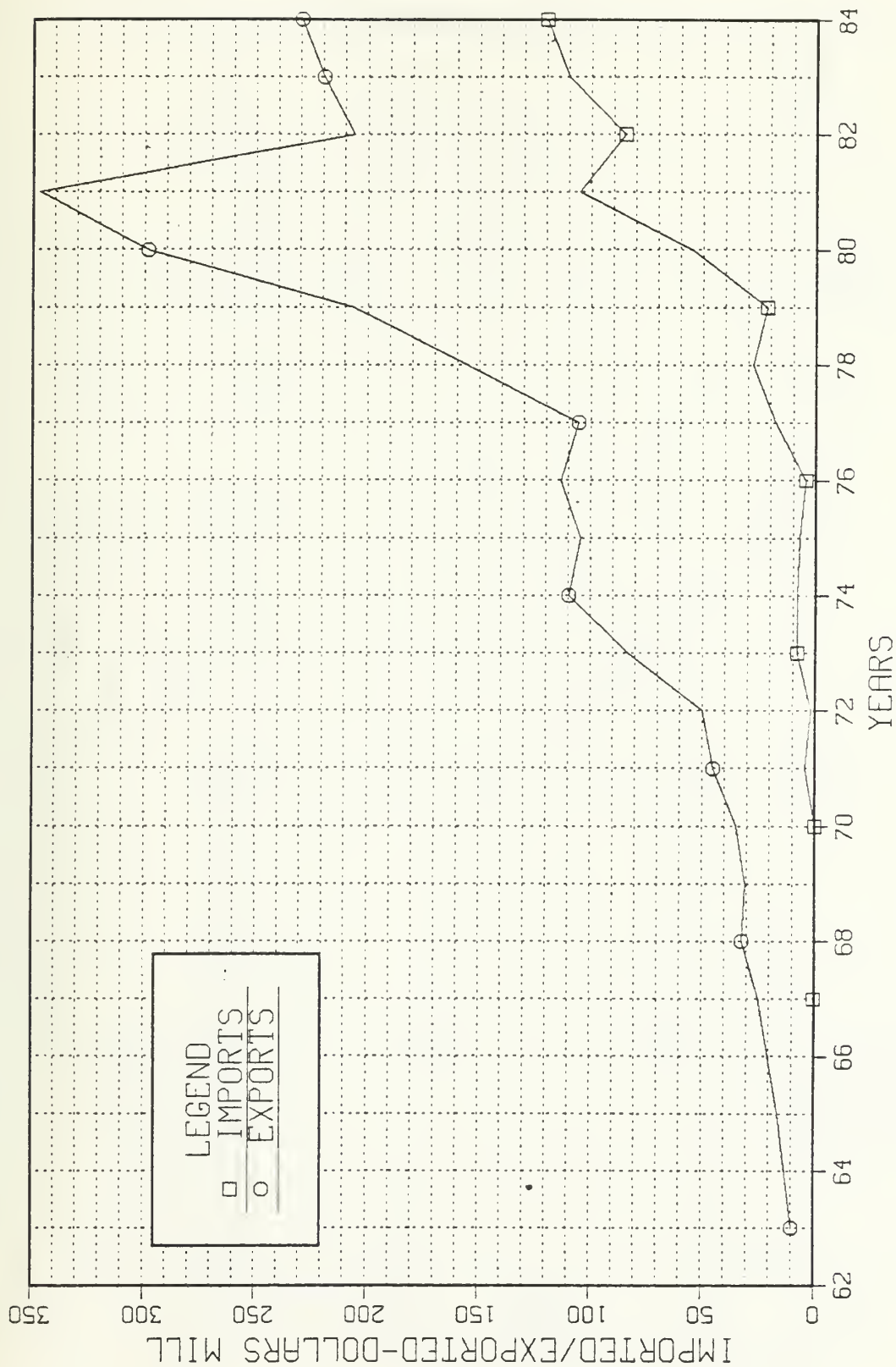


Figure B-8. Helicopters Imported/Exported - Value.

Source: Aerospace Facts and Figures, various years.

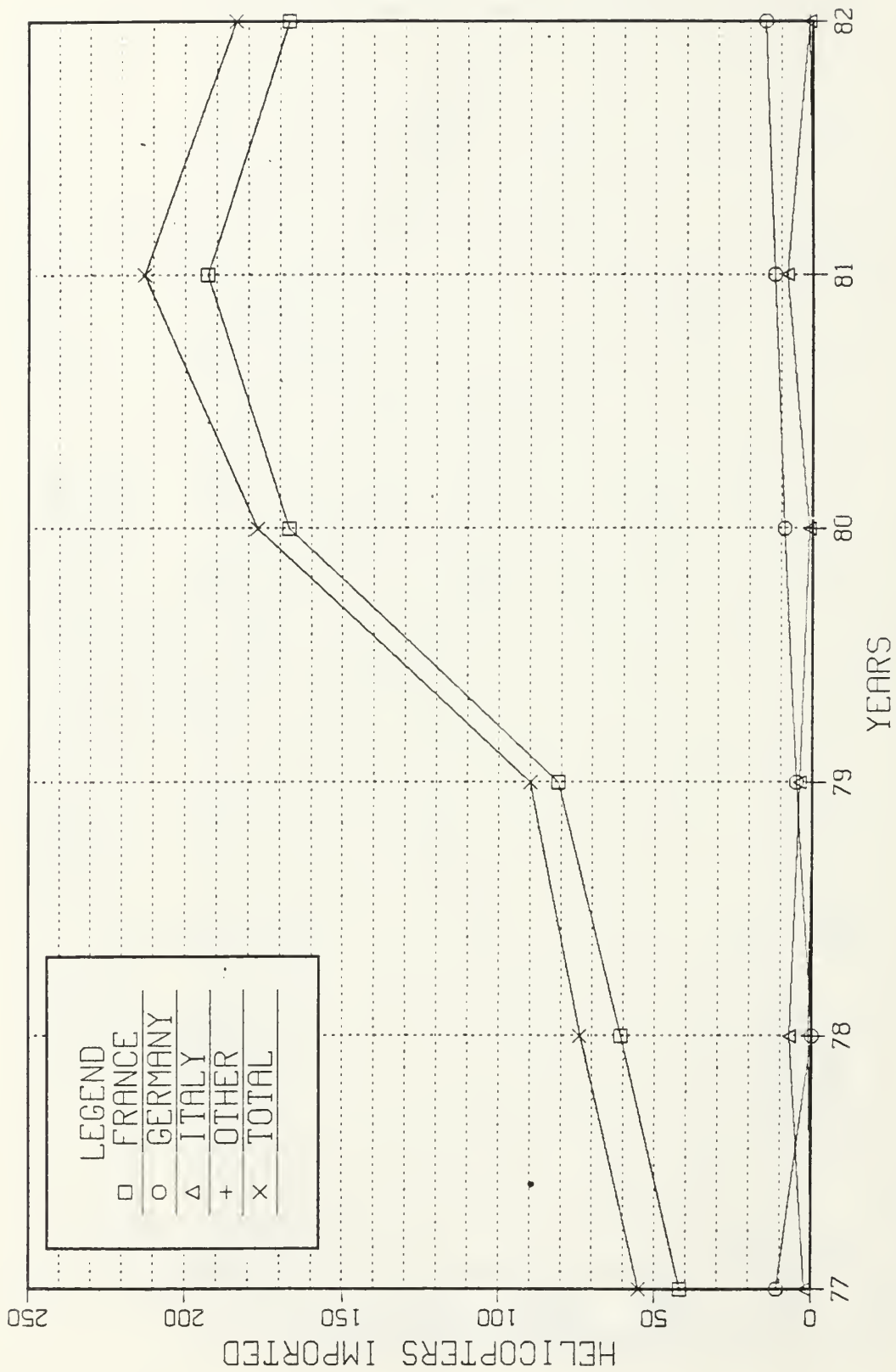


Figure B-9. Civil Helicopters Imported by Region - Units.
Source: Aerospace Facts and Figures, various years.

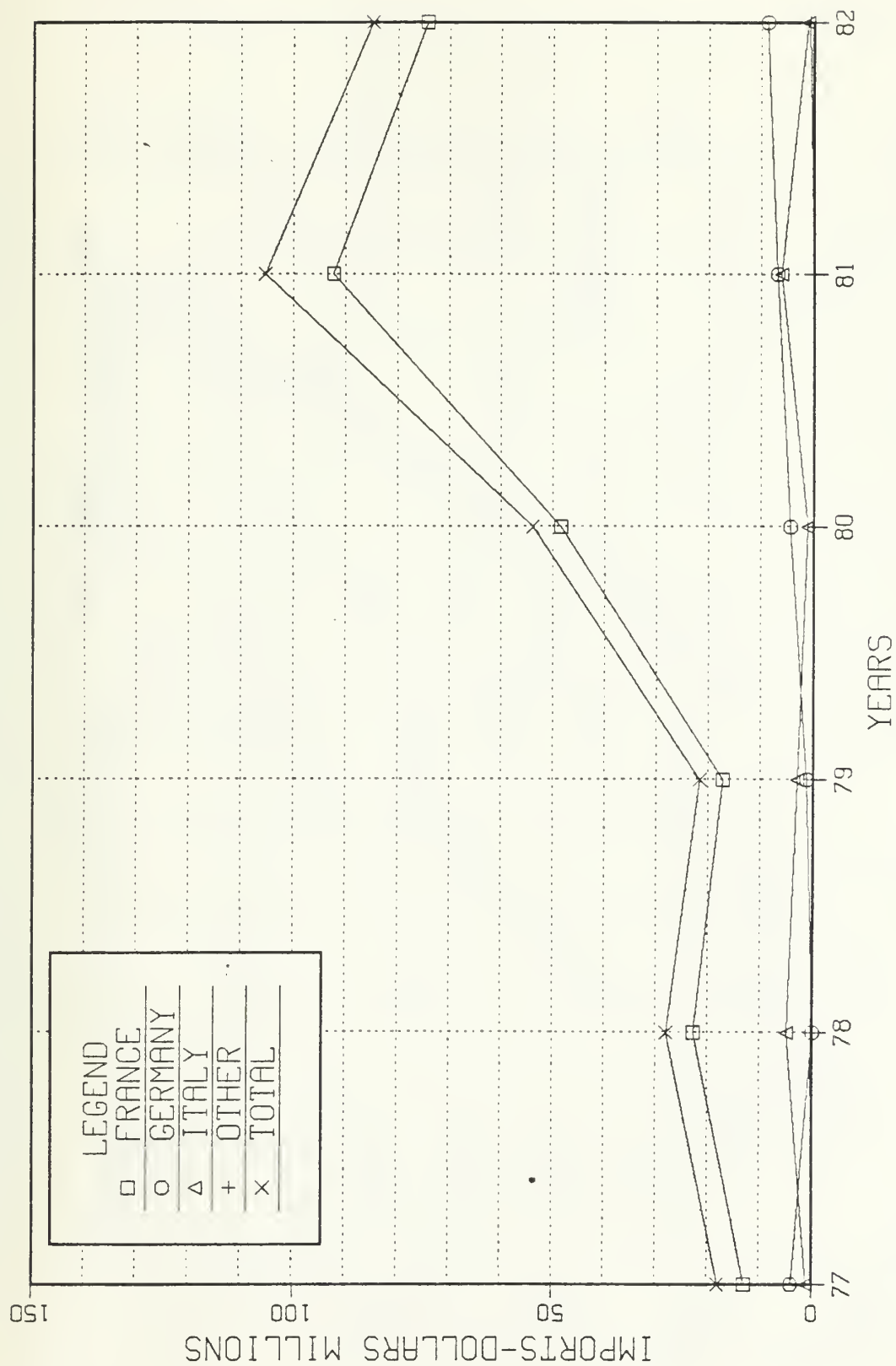


Figure B-10. Civil Helicopters Imported by Region - Value.

Source: Aerospace Facts and Figures, various years.

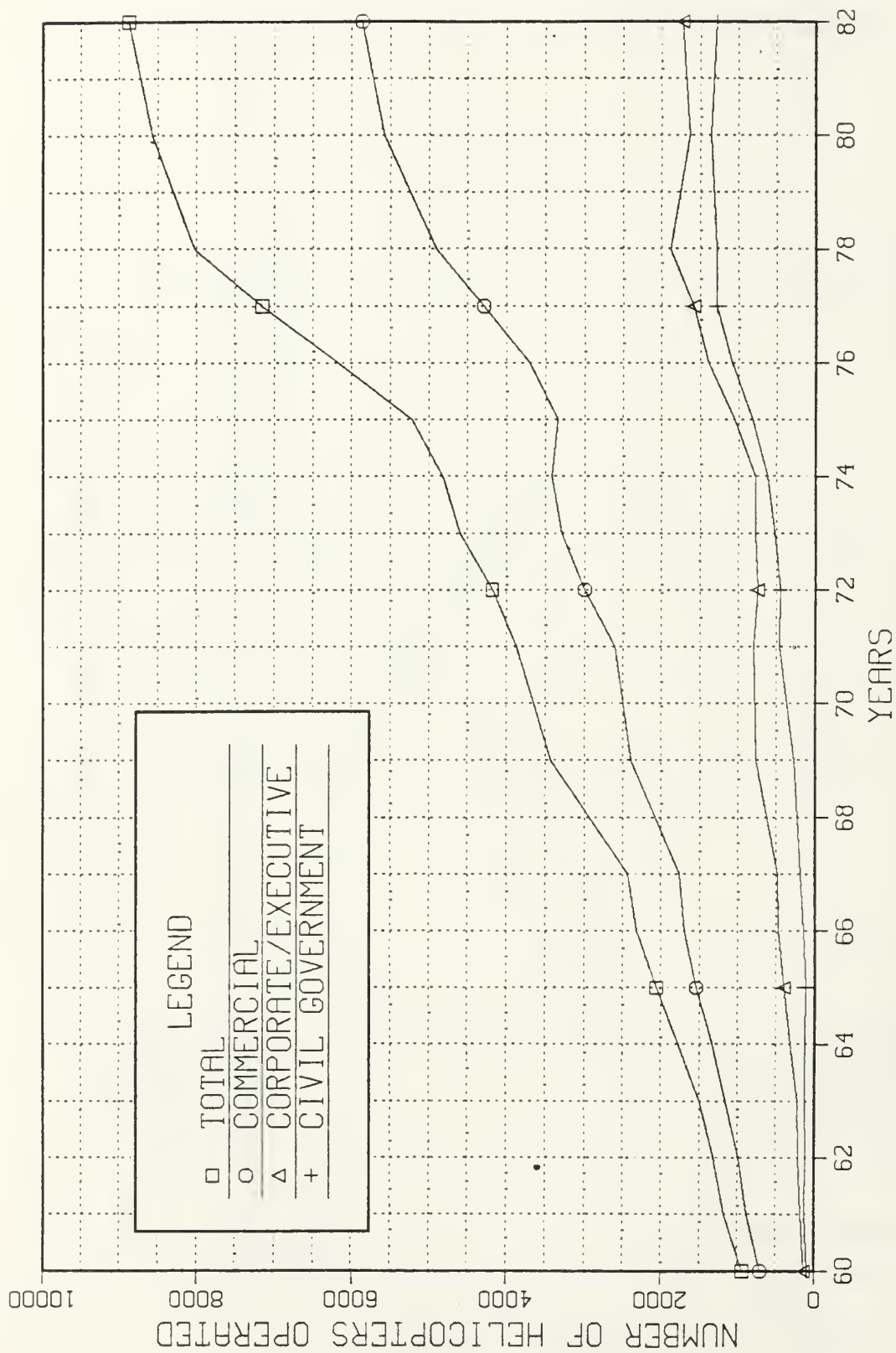


Figure B-11. Civil Helicopters Usage - U.S./Canada/Puerto Rico.

Source: Aerospace Facts and Figures, various years.

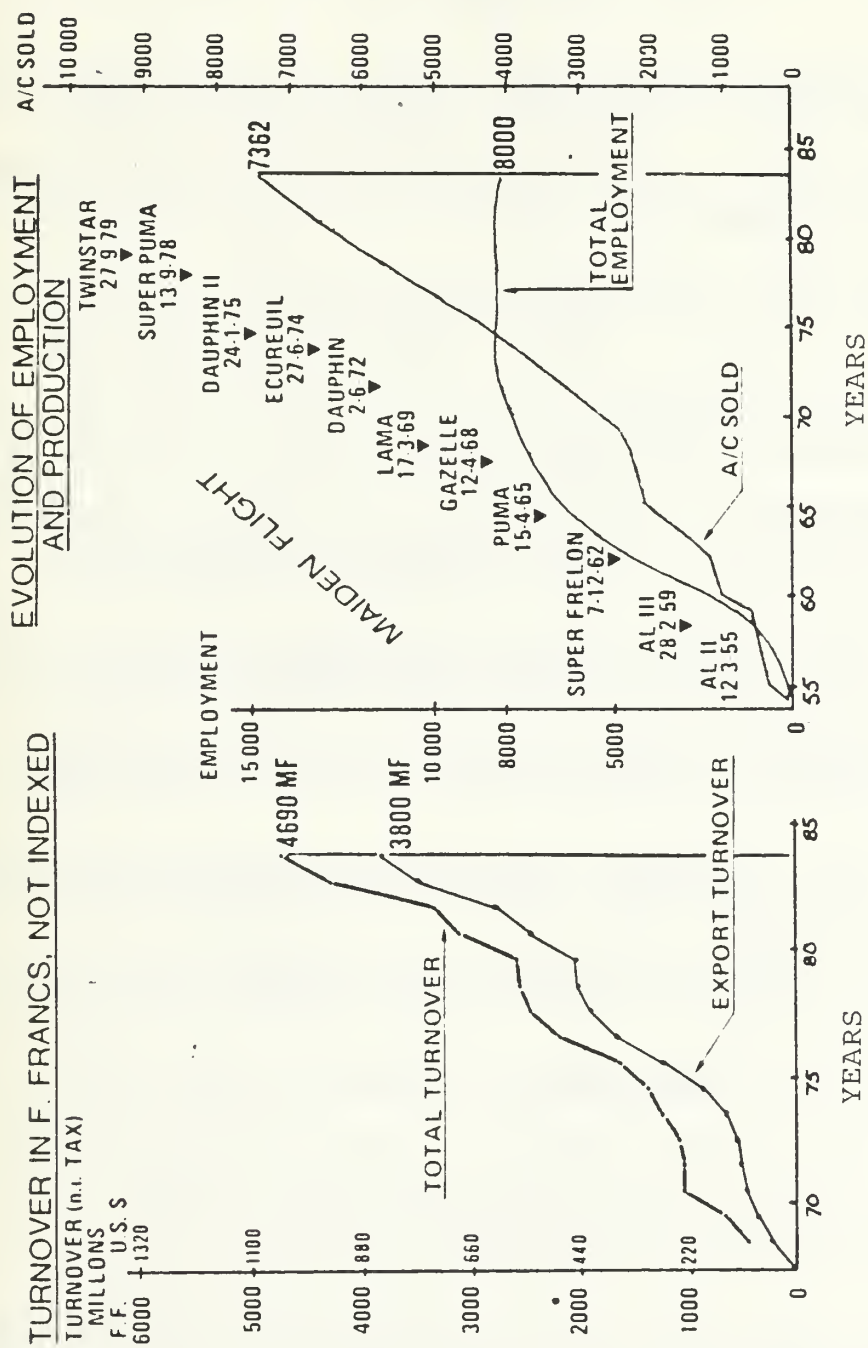


Figure B-12. Growth of Aerospatiale Helicopter Division.

Source: History of the Helicopter-As Told by its Pioneers 1907-1956, Editions France Empire, 1984.

LIST OF REFERENCES

1. National Air and Space Museum, The Age of the Helicopter, Vertical Flight, Smithsonian Institute Press, 1984.
2. Aerospace Industries Association of America, Inc., Aerospace Facts and Figures, 1983/84, Aerospace Research Center, July 1983.
3. Debraggio, Mike, "The American Helicopter Society-A Leader for 40 Years," Vertiflite, May/June, 1984.
4. Toffler, Alvin, Future Shock, Random House, 1970.
5. Young, Warren R., The Helicopters, Time-Life Books, 1982.
6. Wood, Edward C., Lieutenant-Colonel, "The Army Helicopter, Past, Present and Future," Journal of the American Helicopter Society, Volume 1, Number 1, 1956.
7. Boulet, Jean, History of the Helicopter-As Told by its Pioneers 1907-1956, Editions France Empire, 1984.
8. Polmar, Norman and Kennedy, Floyd D., Jr., Military Helicopters of the World, Naval Institute Press, 1981.
9. Keating, Bern, Chopper: The Illustrated Story of Helicopters in Action, Rand McNally and Company, 1976.
10. Brown, Enc, The Helicopter in Civil Operations, Granada Publishing, 1981.
11. "Helicopters," Rotor and Wing International, June 19, 1984.
12. Smith, Leon, Captain, USN-Ret., "European Helicopters-Friend or Foe," Armed Forces Journal, September, 1984.
13. Jane's All the World's Aircraft, 1983-84, Jane's Yearbooks, 1983.
14. Aerospace Industries Association of America, Inc., The U.S. Helicopter Industry, Its Development, World Market and Foreign Competition, The Aerospace Research Center, November, 1983.

15. Gotzhein, Christina, "MBB's Helicopter History-Based on a Solid Heritage," Vertiflite, May/June, 1984.
16. "The Agusta Group," Vertiflite, May/June, 1984.
17. Bogart, Peter, "Soviet Transport Helicopters, An Examination of the Tactical and Technological Aspects," International Defense Review, 8/1979.
18. "Soviet Competition," Aviation Week and Space Technology, June 2, 1969.
19. "Hiller Aviation Files for Bankruptcy," Aviation Week and Space Technology, January 30, 1984.
20. "Army, NASA Lead Testing of Turboshaft Components," Aviation Week and Space Technology, January 16, 1984.
21. Cooke, Richard P., "Junior Jets, Light Powerful Engines Key to Faster, Cheaper Planes of Tomorrow," Wall Street Journal, September 16, 1955.
22. "Army Will Compete 40% of LHX Engine," Aviation Week and Space Technology, July 9, 1984.
23. Condom, Pierre, "Power for Turboprops and Helicopters, the Pace of Change is Faster than it Seems," Interavia, 9/83.
24. Lambert, Mark, "The Helicopter Industry must Change its Ways," Interavia, 5/1983.
25. Lambert, Mark, "Civil Helicopters, 1984 is the Year of Change," Interavia, 1/1984.
26. Steverding, Dr. Bernard, "Research and Development of Helicopters in Europe," Vertiflite, September/October, 1984.
27. Thomason, Tommy, "The History of Helicopters in the U.S. Navy," Vertiflite, May/June, 1984.
28. Siekman, Philip, "The Big New Whirl in Helicopters," Fortune, April 1966.
29. United States Air Force Project RAND, Report R-1604-PR, Directed Licensing: An Evaluation of a Proposed Technique for Reducing the Procurement Cost of Aircraft, Gregory A. Carter, December, 1974.

30. Bacack, Walter W., "Editor's Corner," Vertiflite, September/October, 1984.
31. National Aeronautics and Space Administration, Task Force Report, Advanced Rotorcraft Technology, Office of Aeronautics and Space Technology, 15 October 1978.
32. Lopez, Ramon, "LHX-helicopter Program of the Century," International Defense Review, 5/1984.
33. Rotorcraft Master Plan, U.S. Department of Transportation, Federal Aviation Administration, December 1983.
34. "Introduction," Rotor and Wing International, 19 June 1984.
35. Zugswert, John, "The Crystal Ball is Clearing," Vertiflite, November/December, 1984.

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